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ABSTRACT

An instructional model based on a learning cycle including correlation, analysis, and generalization (CAG) was developed and applied to design an instructional module for grade 8 students in Taiwan, Republic of China. The CAG model was based on Piagetian theory and a concept model (Pella, 1975). The module developed for heat and temperature was administered to test its effects by comparing its use with the same unit in the New Physical Science Curriculum (NPSC). The population was comprised of classes selected from four types of schools. The treatments given were instructional materials, teacher training, pretest, and posttest. Students who were in the experimental group received a copy of the CAG module. Students who were in the control group used the NPSC (1988) material. The major findings were presented as follows: (1) the CAG module tended to improve science learning in an effective way; (2) academic ability and reasoning skills of students were related significantly to achievement; (3) concrete written materials tended to have a positive impact on the science achievement for eighth-grade students; (4) Piagetian logical thinking was found to be a significant predictor for science achievement; and (5) several student misconceptions related to the topics were detected in the tests and interview analyses. (CW)

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AN ANALYSIS OF A MODEL FOR DEVELOPING INSTRUCTIONAL MATERIALS FOR TEACHING PHYSICAL SCIENCE CONCEPTS FOR GRADE 8 STUDENTS IN THE REPUBLIC OF CHINA

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

by

Shun-Yi Hsu, B. S., M. S.

* * * * *

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SE050 991

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CHAPTER I

INTRODUCTION

This chapter includes six sections. The first section describes the background of the study and the need for the study. Section two states the problems and the subproblems. Section three describes the assumptions, delimitations, and limitations of this study. Section four provides a background of the problems consisting of the Piagetian theory, the Piagetian instructional model, nature of science and the concept of concept model. Section five defines selected terms used in this study. Section six is the overview of the following chapters.

SECTION ONE: BACKGROUND AND NEED FOR STUDY

Background of Study

The Republic of China has developed and put into practice a new science curriculum for elementary and secondary schools. The new science curriculum has been used at elementary levels since 1978. The new science curriculum has also been used at secondary levels; it began with seventh grade students who have completed the new curriculum at the elementary level.

The New Physical Science Curriculum (NPSC) is one of the new science curricula for the junior high level in the Republic of China. NPSC was designed to emphasize laboratory and other hands-on activities. The NPSC activities start with objective statements and follow by collecting data. They finish by using discussions related to the collected data. The NPSC looks like a Piagetian learning cycle (exploration, conceptual invention and expansion). It seems, however, that there is little emphasis on the stage of expansion and little connection among activities. The tests of the NPSC indicate that many students have not been learning important objectives of the NPSC program.

The present study was designed to provide empirical knowledge related to the design of instructional materials and activities to facilitate the learning of concepts and process skills in specific topics of science subject matter. An instructional model (a CAG model which is a learning cycle of Correlation, Analysis, and Generalization) which incorporated Piagetian theory and a concept model (Pella, 1975) was developed and applied to design an instructional module for grade eight students. The module developed for heat and temperature was administered to test its effects by comparing its use with the same topic of the unit in the New Physical Science

Curriculum (NPSC).

Need for Study

Science education has been pursued in a random fashion for many years due to differences in value systems and differences in the meanings and use of language. Improving students' reasoning abilities is being stressed as a major goal of science education (Lawson, 1985). Applying cognitive pedagogic theory to the design of instructional strategies and materials to facilitate the learning of school science subject matter and to improve the effectiveness of learning sciences is one way of improving science education. Although there are published instructional materials which use some learning theories, most of them are related to general applications and instructional strategies; very few are related to the applications of learning theories to specific topics of science subject matter designed for specific grade levels.

There is a need to develop modules that apply learning theories to specific topics of science subject matter for specific level students, to test them, and to learn how to modify the modules for further improvement. This study focuses directly on that need.

SECTION TWO: THE PROBLEMS

The major problems of this study were to: (1) develop and analyze an instructional model for a science unit designed for grade eight students; (2) determine the module's impact on science achievement; and (3) identify what should be done to further improve the materials and instruction.

Subproblems

The subproblems related to the major problems are stated as follows:

1. Does the treatment group achieve significantly higher than the control group on the achievement posttest and follow-up test (heat and temperature)?
2. Does data indicate that the unique features of the module (heat and temperature) contributed to the student's success?
3. What students are helped most by the treatment? Do any groups score significantly better than others?
4. Does the treatment aid retention of knowledge? What variables relate to retention if it occurs?
5. Does teacher inservice contribute to the student achievement?
6. Does the evaluation instrument assess learning at more concrete levels appropriately to measure student

understanding of content?

7. How specifically can the CAG model be improved through modification of materials, instruction, and inservice activities?

SECTION THREE: ASSUMPTIONS, DELIMITATIONS, AND LIMITATIONS

Assumptions

The assumptions of this study are stated as follows:

1. The principal goals of science instruction were to transmit cognitive knowledge and process skills to facilitate the daily application of science concepts and process skills.
2. Chinese and mathematics achievement were not measured by the same tests; however, the tests both had equal total score potential. It is assumed that the scores on Chinese and mathematics were a reasonable estimate of the student's academic ability.
3. A paper and pencil test could be used to measure the desired concepts and process skills.
4. Since the topics in the CAG module were the same as the topics in the NPSC, it was assumed that teachers in both the experimental and control groups were familiar with the content areas.

Delimitations

1. The inservice training for teachers of the experimental group was related to the teaching strategies for the CAG module.

2. Four schools were selected to be representative of four types of schools in Taiwan the Republic of China. There were (a) selective schools, (b) urban schools, (c) suburban schools, and (d) town and country schools.

Rural schools were not selected because less than four percent of the total student population were included in this type of school in Taiwan, the Republic of China.

3. Twelve classes were randomly selected from the four schools. There were (a) two classes from the selective school, (b) four classes from the urban school, (c) two classes from the suburban school, and (d) four classes from the town and country school.

4. The items on the pretest assessing prior knowledge were related to the specific science topics included in the unit. These were temperature, heat, specific heat, and heat transfer.

5. Three types of Piagetian tasks (proportional reasoning, propositional reasoning, and combinatorial reasoning from the concrete level to the formal level) were included in the pretest.

6. Mathematics skills (including concepts of number,

equation solving, and data interpreting skills) related to the learning of specific topics in the unit were included in the pretest.

7. The available Chinese and mathematics test scores were used for analyses.

8. The items of the posttest were based on the objectives of NPSC program.

9. The items of the follow-up test were the same as the items of the posttest.

Limitations

1. Results of this study apply only to the four schools studied.

2. Results of the study do not apply to the rural schools.

3. Results of the study apply only to the eighth grade students.

4. Contacts between students within schools were undetermined.

5. Out-of-school learning was undetermined.

6. Results of this study can not be generalized to other units of study without further testing.

SECTION FOUR : BACKGROUND OF THE PROBLEMS

Piagetian Theory

Piaget proposed that the development of intelligence in human beings consists of a series of stages; the approximate ages which correspond to the stages (Ginsburg & Copper, 1988; Lefrancois, 1975) are:

1.	Sensorimotor stage	0 to 2 years old;
2.	Preoperational stage	2 to 7 years old;
3.	Concrete operational stage	7 to 11 years old;
4.	Transitional stage	11 to 12 years old; and
5.	Formal operational stage	12 to 15 years old.

In the sensorimotor stage, children try to establish their perceptions to make connections with the environment in which they live. The sensorimotor period is characterized by a motoric representation of the world. Among major achievements during this period are the development of language, the development of the object concepts, the development of control of schemata, and the recognition of cause and effect relationships.

In the preoperational stage, children's reasoning is characteristically transductive --- that is, it proceeds from particular to particular. Children's reasoning during this stage is egocentric, perception-dominated, and irreversible. Their abilities are limited to reasoning about conservation of quantities, mass, or area. In the concrete operational stage, children have become relatively decentered. That is, they are no longer so egocentric or so perception bound. They can apply rules of logic to classes, relations, and numbers. But they are still incapable of applying rules of logic to objects or events that are not concrete. Between the age of 11 to 12 or 13, after the concrete level and before the full formal level, adolescents tend to be in what is called a transitional stage. They can reason from hypothetical to real and from real to hypothetical if some concrete data or pictures are provided to help them. In the formal operational stage, adolescents can reason from hypothetical to real, or from real to the hypothetical. They can apply a formal set of rules of logic. This order of stages does not appear to happen in a different sequence, i.e., the formal stage does not occur before the concrete state has been attained.

Piagetian theory has five facets of educational implications for science curriculum materials as follows:

1. Respect of differences; curriculum materials should be constructed to allow for the differences between children and adolescents in reasoning abilities and the differences of characteristics at different stages.
2. Limit of knowledge; curriculum materials need to be

constructed based on limitations in learning capability at different stages.

3. Curriculum materials need to be more effectively organized based on cycles of learning.

4. Reasoning skills need to be appropriate and need to be developed.

5. Time and activities need to be provided for the learners to integrate the information into their knowledge structures.

The Piagetian Instructional Model

Piagetian theory proposes that a child's adaptation to his environment is accomplished through two ways; assimilation and accommodation. Assimilation involves making a response to what has been already acquired. Accommodation is a modification of a response. Whenever a child responds in terms of activities he already knows, it is said to be assimilating. On the other hand, when a change in behavior takes place by assimilating a new stimulus it is called accommodation. Assimilation takes place under a new situation that is somewhat familiar to the pre-existing knowledge which the learner has. Accommodation, on the other hand, takes place when a new situation is somewhat strange (Lefrancois 1975).

An instructional model developed by the researcher and based on the Piagetian theory is shown in Figure 1.1. This model was related in developing the CAG model in this study. See Chapter III.

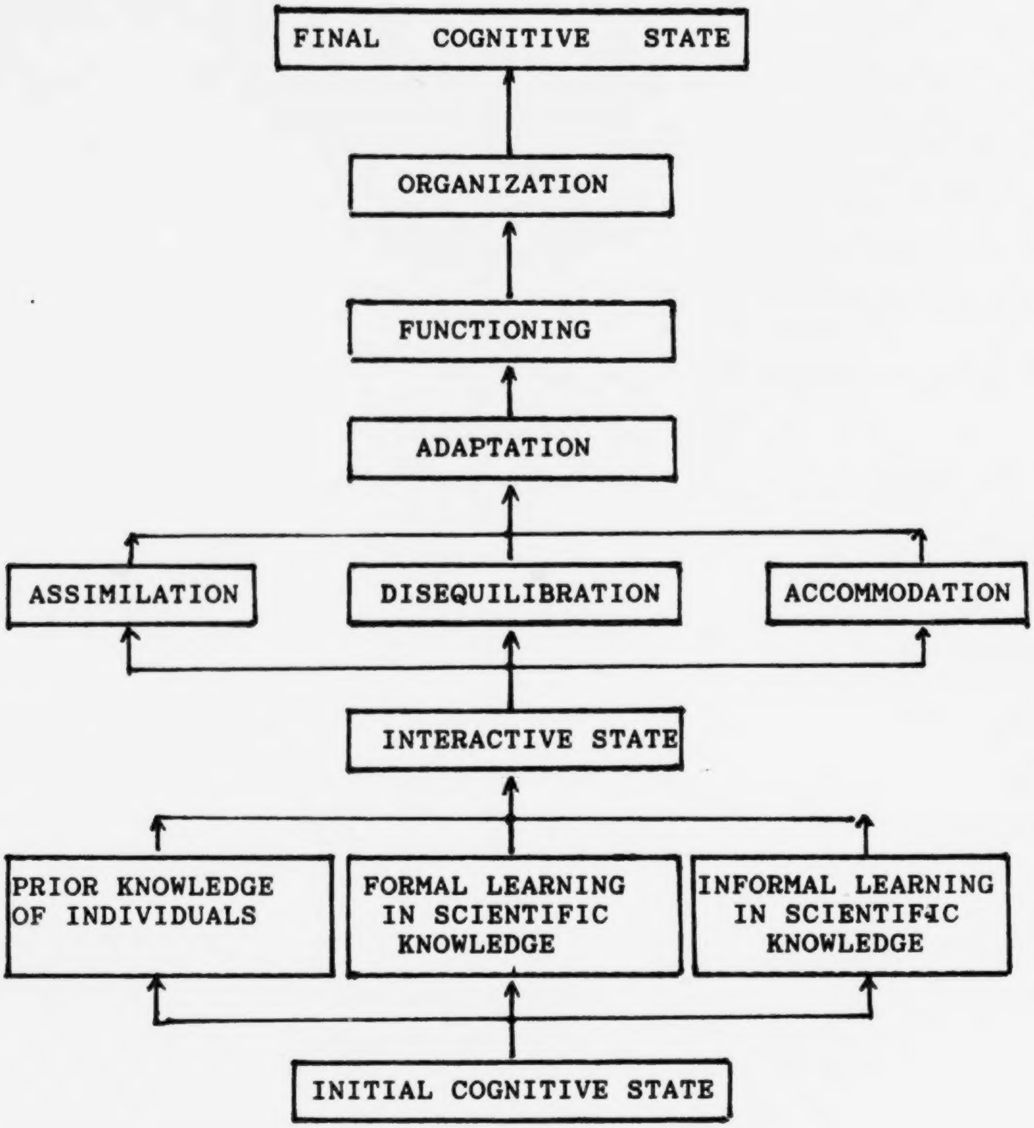

FINAL COGNITIVE STATE
ORGANIZATION
FUNCTIONING
ADAPTATION
ASSIMILATION
DISEQUILIBRATION
ACCOMMODATION
INTERACTIVE STATE
PRIOR KNOWLEDGE OF INDIVIDUALS
FORMAL LEARNING IN SCIENTIFIC KNOWLEDGE
INFORMAL LEARNING IN SCIENTIFIC KNOWLEDGE
INITIAL COGNITIVE STATE

FIGURE 1.1. The Piagetian Instructional Model Developed by the Researcher.

A learning cycle (exploration, conceptual invention, and expansion) was developed by Karplus for SCIS. A functioning model and a teaching model was developed by Renner et al. (1983). Comparison of a functioning model and teaching model of learning cycle is presented in Figure 1.2.

Functioning model		Teaching model
Assimilation	⟷	Exploration
Disequilibration & Accommodation	⟷	Conceptual invention
Organization	⟷	Expansion of ideas

Figure 1.2 Functioning Model Versus Teaching Model --- Piagetian Learning Cycle (Renner et al. 1983).

The tasks involved in the phase of exploration should result in assimilation of learning. The tasks provide students with time and opportunity to assimilate data about the concept that the teacher wants them to learn. But, since the data will be new to the students, their collection and interpretation give rise to many questions such as, "What's this?", "How does this work?", "What does this finding mean?" and so on. Those questions are evidence that disequilibrium is presented and that the students are asking for assistance in putting their thoughts in accord with the things they have just explored. In other words, they are ready for accommodation.

Evidence of readiness can be used by the teacher to lead the students to consolidate their data and arrive at the concepts underlying the entire experience. The tasks involved in the phase of conceptual invention should result in tending to a equilibrium of the learner's cognitive structure.

The tasks involved in the expansion of ideas should result in the reorganization of the learner's cognitive structure (the learner should formulate a new system in his cognitive structure).

Nature of Science

Science is a systematic objective search for understanding of the natural and human world, a body of knowledge, formed through continuous inquiry. Science is also characterized by use of an empirical approach, statements of generality (laws, principles, theories) and testing to confirm, refute, or modify knowledge about natural phenomena. As Nash (1963) says, "Science is a way of looking at the world." In the words of Einstein (Albert Einstein in Booth, 1962), the object of all science is to coordinate our experiences and bring them into a logical system. Bohr (Niels Bohr in Booth, 1962) says that the task of science is both to extend the range of experience and reduce it to order. Helgeson (1967) notes about science:

> The understanding of nature is a product of science and is expressed in the form of concepts that explain the facts of the universe. Such a product is not a finite, static body of knowledge, although science does deal with facts, which might be considered finite, but is rather a dynamic series of approximations of the truth. The concepts that serve to explain nature, then, are to be considered as tentative and useful in the degree to which they are able to predict future phenomena (p. 9).

The knowledge of science, according to the point of view of the cognitive psychologist, can be divided into two major domains which are procedural knowledge and propositional knowledge. Generally speaking, procedural knowledge refers to one's ability to carry out the various procedures as steps involved in performing either a psychomotor or intellectual task (Gagne, 1977); included here would be many skills related to science education. Propositional knowledge, on the other hand, refers to the systematic and organized body of knowledge that we have about something (Shuell, 1987). Pella (1975) proposed that science, that is empirical science, has three major objectives;

> 1. to describe natural structures, functions of structures, and phenomena (events), 2. to establish consistencies (sometimes called empirical laws, principles, or generalizations) that are functional in explaining and predicting natural structures, functions of structures, and phenomena (events), and 3. to develop theories that function in unifying, explaining, and predicting new empirical laws (p. 5).

Concepts of science have been described as: ordered information that enables a particular thing or class of things to be differentiated from and also related to other things or classes of things. A concept deals with the meaning an individual attaches to a word or other symbol rather than with the mere fact that any given symbol is associated with any given object (Cronbach, 1954). A concept is a mental image formed by a generalization from the particular, an idea of what a thing in general is to be (Hunt, 1962). A concept is an idea, a mental image of an action or thing, a generalization about related data. It is an understanding of the immediate based upon the impact of present impressions on past experience, usually labeled with a verbal symbol or symbols (Kranger, 1963).

The Concept of Concept Model.

Pella (1975) has classified science concepts to have three levels of sophistication: descriptive, comparative, and quantitative. He identified the descriptive as the lowest level and quantitative as the highest level. A descriptive concept identifies an object, event, or phenomenon as a member of a class of objects, events, or phenomena. Science uses concepts of this kind largely for description of observational findings for the formulation of initial, relatively imprecise, empirical laws.

Comparative concepts make use of descriptive concepts but also make use of the idea of "degrees of" or "extent of" rather than merely "present or absent." Comparative concepts indicate how one object or event is related to another in terms of more, less, or the same. Quantitative concepts use a quantitative language in which there are symbols for functions that have numerical values that represent measures. Quantitative concepts serve to show how an object, function, or phenomenon relates to an accepted standard to which a numerical value has been assigned. Thus, the laws of nature are more precisely described.

Pella (1975) referred to the number of variables concerned as complexity; the greater the number of facts, laws and concepts included within a concept the greater its complexity, and the higher the order of the derivatives involved the greater the complexity. His concept model illustrating the three dimensions of concepts (sophistication, abstractness, and complexity) is illustrated in Figure 1.3. While Pella identified three dimensions of concepts, only the sophistication dimension (descriptive concept, comparative concept, and quantitative concept) was related in the developing the module and the evaluation items.

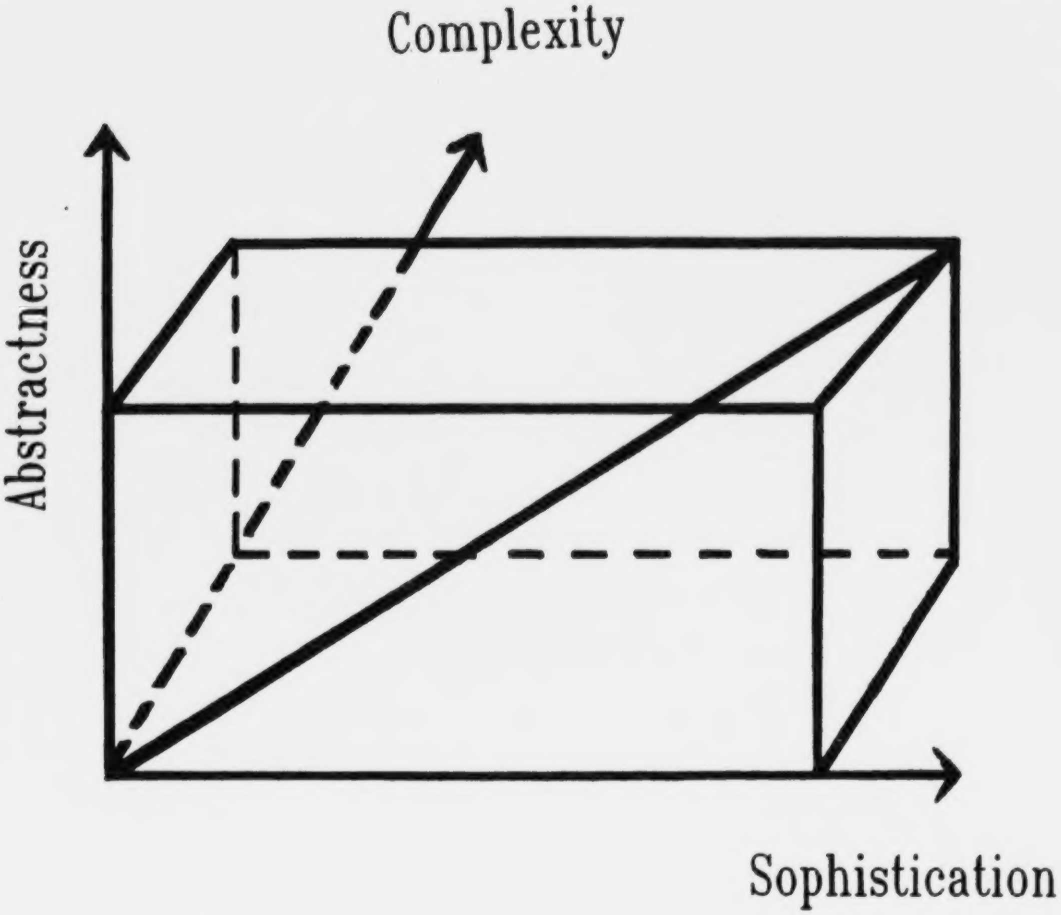

Complexity
Abstractness
Sophistication

Figure 1.3. Pella's Concept of Concept Model(Pella, 1975)

SECTION FIVE: DEFINITIONS OF THE TERMS

The definitions of concern to the study are as follows;

Cognitive learning;

--- the extent to which the subjects "know, comprehend, apply, and analyze" the cognitive subject matter as measured by the researcher- made test designed in accord with the principles of Bloom's taxonomy of the cognitive domain and Piaget's stages of reasoning.

Concept;

--- a symbol or group of symbols that stands for a class or group of objects or events that possess common properties and may be either verbal or nonverbal (Houston, 1981).

--- a concept is an idea, a mental image of an action or thing, a generalization about related data. It is an understanding of the immediate based upon the impact of present impressions on past experiences, usually labeled with a verbal symbol or symbols (Kranzer, 1963, p. 6).

Process skills;

--- as defined by Science-A Process Approach (S-APA). S-APA divided the 13 skills into two types-- basic and integrated. The basic science process are observing, classifying, communicating, measuring, and using space/time relations. These skills provide a foundation for learning the complex integrated skills---controlling variables, interpreting data, formulating hypotheses, defining operationally, and experimenting (Padilla, 1983).

Proportional reasoning (Karplus, 1979; Krajcik, 1987);

1. The concrete level;

--- Making inferences from data under conditions of constant ratio equal to a small number (e.g., if two pieces of candy cost 25 cents, four pieces cost 50 cents).

2. The transitional level;

--- Making inference from the data under conditions of a constant ratio not equal to a small whole number with some concrete experiences provided.

3. The formal level;

--- Making inferences from the data under conditions of a constant ratio not equal to a small whole number with no concrete evidences provided.

Propositional reasoning (Karplus, 1979; Krajcik, 1987);

1. The concrete level;

--- Using a postulate or axioms of a theory to derive consequences based on the factual events or situation.

2. The transitional level;

--- Using postulates or axioms of a theory to derive consequences based on part of the factual evidence or situation.

3. The formal level;

--- Using postulates or axioms of a theory to derive consequences without regard to the factual basis of the postulates (e.g., making inference from the theory according to which the earth's crust consist of rigid plates moving in relation to one another).

Combinatorial reasoning (Ginsburg, & Copper, 1988; Sayer, 1975);

1. The concrete level;

--- Estimating the number of permutations possible with two variables.

2. The transitional level;

--- Estimating the number of permutations possible with more than two variables in one dimension by providing a concrete picture.

3. The formal level;

--- Estimating the number of permutations possible with more than two variables in multiple dimensions.

Correlational reasoning (Karplus, 1979; Krajcik, 1987);

1. The concrete level;

--- Recognizing a simple relationship between two variables.

2. The transitional level;

--- Recognizing relationships among variables by providing some related concrete evidence.

3. The formal level;

--- Recognizing relationships among variables in spite of unpredictable fluctuations that mask them (e.g., drunk driving is associated with increased accidents even though sober drivers also have accidents, and many intoxicated people do not have accidents).

Types of schools;

1. selective schools;

--- The junior high schools that had a large portion of their students enrolled in the top senior high schools by the entrance examinations.

2. Urban schools;

--- Schools located in the center of large cities.

3. Suburban schools;

--- Schools located in the suburban areas of large cities.

4. Town and country schools;

--- Schools located in the small town or in the country.

SECTION SIX: OVERVIEW

This dissertation is organized into five chapters. The first chapter contains the introduction and consists of six sections.

The second chapter presents a review of related literature which is divided into eight parts in the following sequence: (1) Research findings on science achievement; (2) Reasoning skills and physics learning; (3) Instructional materials and strategies; (4) Problem solving; (5) Development of schemata; (6) Cognitive learning; (7) Inquiry learning and laboratory work; and (8) Studies on heat and temperature.

The third chapter presents the method and procedures including six parts as follows: (1) Population and sample; (2) The development of instructional material; (3) The development of instruments; (4) treatments; (5) Data collection; and (6) Analyses of data.

The fourth chapter reports the results of the analyses of the data.

The fifth chapter presents a summary of the findings, conclusions, discussion, implications, and recommendations.

CHAPTER II

THE RELATED REVIEW OF LITERATURE

This chapter consists of eight sections related to students' achievement on science, and development of the CAG model and module. Section one describes research findings of physics learning. Section two describes reasoning skills and physics learning. Section three includes instructional materials and strategies. Section four describes problem solving. Section five relates to the development of schemata. Section six describes cognitive learning. Section seven is related to inquiry learning and laboratory work. Section eight describes studies on heat and temperature.

SECTION ONE: RESEARCH FINDINGS ON SCIENCE LEARNING

A Perception of Physics Learning

Welch et al. (1984) reported the 1981-1982 science enrollment in the U.S. public and private secondary schools. They found a sharp decrease in high school enrollment in science in the upper grades. Eighty-two percent of the 10th grade were enrolled in science, but less than half the juniors and only a third of the 12th graders sign up for any science. About 20 percent of the students were taking physics.

There is general agreement among physics instructors and students that physics is difficult to teach and learn (Kolody, 1977). The instructional problem has been discussed at length in the literature of physics education and various underlying causal factors contributing to the problem have been suggested (Gerson, & Primose, 1977; Hudson, & McIntire, 1977). The first perspective assumes that learning difficulties occur when the learner is deficient in skills which are assumed to be prerequisite to the study of physics (Arons, 1976; Renner, Grant, & Sutherland, 1978). The second perspective is that students enrolled in introductory physics courses have firmly embedded conceptualizations of prior knowledge of physics and that those conceptualizations are in clear conflict with the canonical view of the subject matter domain which the student will be required to learn (Champagne, Klopfer, & Gunstone, 1982). The third perspective is that students know a lot of physics but do not relate it to the everyday world. The difficulties are compounded by the fact that many of the terms used in science class are also used in everyday life--- terms such as acceleration, momentum, speed, heat, and force. The meanings of those terms as used by physicists are quite different from the way in which they are used in everyday life.

Bowen and Kenealy (1985) have proposed that there were at least two reasons why many students have been discouraged from choosing physics, even though they might have the capacity to gain an understanding of the basic ideas and the ways of thinking involved in physics. First, the study of physics is still perceived by students and parents to be too demanding for anyone but the most able, well prepared, and motivated students. Second, its purpose is still perceived to be the training of a narrow specialty. They recommended that the image and character of physics teaching in the schools could be changed by decreasing the difficulty of instructional materials and improving the laboratory experiments.

Scholastic Ability and Physics Learning

Scholastic ability includes mathematical ability and language ability. Fleming and Malone (1983) conducted a meta-analysis on the relationships of student characteristics and student performance in science using studies covering the years from 1960 to 1981. They reported a mean correlation between physical science and mathematics achievement of .48. The mean correlation (eight studies) between language ability and physical science achievement was .55. The correlation between general ability and physical science achievement was .49.

Scholastic ability was identified as a significant predictor for science achievement in several studies (Brown, 1983; Galitsis, 1986; Kahl, 1982; Lee, 1987; Welch, 1985). Lee (1987) analyzed the relationships between prior science achievement, instruction, family background, and science achievement for elementary students in the Republic of China. She found that mathematics and Chinese accounted for 20 to 30 percent of the variance to explain the science achievement.

Prior Science Knowledge

There have been several reviews of research (Lee, 1987; Welch, 1985) in which prior learning has been analyzed for its effect on achievement. Results have generally yielded correlations of .30 to .50 and accounted for 10 to 25 percent of the explained variance for upper grades, and lower grades, respectively. In general, more variance was explained as grade level increased. Wolf (1979) reported that when home environment and scholastic ability were also analyzed, prior knowledge contributed 0, 3, and 9 percent of the added variance of science achievement corresponding to 10-year-old, 14-year-old, and 12th grades. Lee's (1987) results identified science achievement of the previous semester as the strongest predictor for Chinese elementary students. It added ten to 16 percent of the variance when the scholastic ability also was analyzed.

Science Achievement and Gender

Fleming et al. (1983) reported the relationships of gender with science achievement, cognitive level, and science attitudes by grade level and subject areas. A mean effect size (eleven studies) of .30 favoring male students was found on a combined cognitive level in physical science. A mean effect size (eleven studies) of .32 favoring males was calculated on science achievement at the middle school level (7-9). Weaker relationships between science achievement and gender in the elementary (effect size=.04) and high schools (effect size=.015) were found. It was concluded that students at the middle school level were not just in transition physically, but intellectually and emotionally as well. This period of transition might have implication for refinement of science teaching strategies at the middle school level to take advantage of the strengths of both sexes.

SECTION TWO: REASONING SKILLS AND PHYSICS LEARNING

A large number of studies conducted during the 1960s and 1970s sought to replicate and extend Inhelder and Piaget's (1958) findings to larger and more diverse groups of adolescents. Findings were generally consistent with those of Inhelder and Piaget with some significant exceptions (Lawson, 1985), particularly on the tasks in which formal reasoning was evidenced. (Its attainment appeared far from universal.) In some studies, such as that conducted by Dale (1970), only 25 percent of the 15-year-olds demonstrated even rudimentary ability with formal reasoning processes.

Many researchers have found that student achievement has a high correlation with formal logical reasoning skills such as identifying and controlling variables, correlational logic, propositional logic, combinatorial logic, proportional logic, and probabilistic logic (Lawson, & Blake, 1976).

A reasoning pattern has been defined as "an identifiable and reproducible thought process directed at a type of task" (Karplus, 1979) and can be classified as concrete and formal processes. Examples of reasoning patterns applied at the concrete and formal levels are presented as follows (Karplus, 1979; Krajcik, & Haney, 1987):

1. Examples of reasoning patterns applied at the concrete level.

Classification-- separating a group of objects into several groups according to an observable property (e.g., distinguishing consistency between acids and bases according to the color of the litmus paper).

Conservation-- realizing that an observable quantity remains the same if nothing is added or taking away, even though it may appear different (e.g., when all the water in a glass is poured into an empty bottle, the amount of originally in the glass equals the amount finally in the bottle--unless some was spilled).

Proportional reasoning-- making inferences from data under the conditions of a constant ratio equal to a small whole number (e.g., if two piece of candy cost 25 cents, four pieces cost 50 cents)

2. Examples of reasoning patterns applied at the formal level.

Classification-- arranging a group of items (objects or abstractions) into a multi-level hierarchy according to observable or intangible properties (e.g., classifying the member states of the United Nations according to their form of government, economic system, and standard of living).

Conservation-- realizing that certain properties of a system remain the same if nothing is added or taken away, but that this reasoning can not be applied to all properties (e.g., the total angular momentum of an isolated system is constant, but some students can gain knowledge without depriving others of knowledge).

Proportional reasoning-- making inference from the data under condition of a constant ratio not equal to a small whole number (e.g., if twelve pieces of candy cost 16 cents then fifteen pieces cost 20 cents).

Correlational reasoning--recognizing relationships among variables in spite of unpredictable fluctuation that mask them (e.g., drunk driving is associated with increased accidents even though sober drivers also have accidents, and many intoxicated people do not have accidents).

Propositional reasoning-- Using postulates or axioms of a theory to derive consequences without regard to the factual basis of the postulates (e.g., making inference from the theory according to which the earth's crust consists of rigid plates moving in relation to on another).

Padilla et al. (1983) reported a study to examine if any relationship existed between integrated process skills and logical thinking abilities of middle school students. The conclusions showed a moderate to strong relationship between process skills and logic thinking abilities. The correlation of .73 between the two total test scores is evidence of a substantial relationship between a student's ability to use science process skills and to think logically.

A study by Champagne, Klopfer, Desena, & Squires (1981) investigated students' preinstructional conceptions of the motion of objects. They identified that the following are characteristic cognitive states of uninstructed physics concept understanding.

1. Concepts are poorly differentiated.
2. Rigorous meaning of physics concepts are different from the everyday meanings attributed to the terms.
3. Propositions are imprecise and the imprecision derives from several different sources;
   a. students assign different meanings for technical concepts than do scientists e.g., more force means more speed.
   b. error in interpretation of scale (Gunstone, & White, 1981), e.g., gravity pulls harder on objects that are closer to the earth. and
   c. misconceptions due to inappropriate formulation of general rules from experiences in the real world.

In recent years, the mainstream of both cognitive psychology and science education tend to agree that knowledge consists of complex networks of information and skills and that the learning of new knowledge occurs in the context of and is heavily influenced by pre-existing knowledge; the prior knowledge which an individual brings to a given situation determines how the individual will respond and learn. This concern for prior knowledge has been evident in: (a) the concern for misconceptions that students hold about the material they are studying and the difficulty that is involved in trying to overcome them (Champagne, Klopfer, & Gunstone, 1982; Hewson & Hewson, 1983), and (b) appropriate ways of describing students' cognitive structure (Shuell, 1987).

One of the most severe and widely prevalent gaps in the cognitive development of students at secondary and early tertiary level is the failure to have mastered reasoning involving ratio (Arons, 1983). This disability among the large number of students who suffer from it is one of the most serious impediments to their study of science. Arons noted that many students have great difficulty giving a verbal interpretation of the ratio of 500g/30cm or its reverse 30cm /500g. In Piagetian terminology, the word "operations" denotes reasoning processes that can be reversed by the user. Thus, students who can calculate the unit cost, but do not recognize the interpretation of the ratio are not reversing the reasoning and have not attained an operational level in this context. Arons (1984) proposed that reversal of the line of thought, enhances development of what Piagets call "Operations" where the context is abstract rather than concrete, and that the learner can thereby be helped to secure his command of "formal operations."

In dealing with ratio reasoning, teachers accept the words "in," "for each," "corresponds to," "goes with," "is associated" or "combines with" better than the word "per," because "per" is a technical term. Very few students who encounter trouble with arithmetical reasoning know what it means (Arons, 1983).

A powerful way of helping students develop a mode of reasoning is to allow them to review the same reasoning from more than one perspective. In the case of arithmetical reasoning, a very useful, attractive perspective is that of graphical representation.

SECTION THREE : INSTRUCTIONAL MATERIALS AND STRATEGIES

Curriculum Materials

Fundamental variables usually considered in science curriculum development are: (1)) science knowledge; (2) scholastic abilities and interests of individuals; (3) the application of learning theories; (4) the degree of teachers' involvement and their characteristics; and (5) social needs. Curriculum designers and developers tend to look at: (1) intended curriculum; (2) implemented curriculum; and (3) actual curriculum in their decision making. Tyler's model (1949) significantly influenced the development of science curricula in the 1957-1975 period.

Shymansky et al. (1983) did a meta-analysis of 130 studies that investigated the effectiveness of secondary level National Science Foundation (NSF) curricula in comparison to traditional science programs. Their outcome measures consisted of cognitive tests, affective scales, process and analytical skills, and creativity. They found a mean effect size of .37 in favor of the NSF curricula. However, specific areas stressed in these innovative curricula showed even greater differences. The mean effect size for process skills was .61, for analytical skills, .71 and for creativity, .71. Weinstein, Boulanger, and Walberg (1982) analyzed 33 studies from the United Stated, Great Britain, and Israel and found 151 separate comparisons in them. The mean effect size was .31 with a standard deviation of .70. This is in close agreement with Shymansky et al. (1983) and Wise and Okey (1983) results. The curriculum to which students are exposed does make a difference in what students learn. The research literature is replete with curriculum studies and most find that students learn the content to which they are exposed.

Teacher Training

There is some evidence that some materials can be written to improve student learning and achieve significant gains (Roth, et al., 1987). One of the reasons for rewriting materials to achieve gains with no teacher education is to improve the implementation of materials and also to reduce costs of inservice education. This procedure is being used by several curriculum developers to develop units or modules through the use of misconception research and trial with students.

Some materials are developed that are designed to be implemented after inservice education of teachers. Sweitzer (1983) conducted a meta-analysis to examine the effectiveness of inservice training for preparing teachers to teach inquiry. Sweitzer noted a mean effect size of .77 for 153 different studies; teachers who receive the training tended to outperform the comparison groups on measures of science content, process, attitude toward science, and on desired teaching behaviors (e.g., questioning). These data provide support that training does have an effect on teacher performance.

When inservice was not specific or when the instruction was not used in a short period the impact often was not strong (usually not significant) (Anderson, 1983).

No significant difference was found between elementary teachers who received inservice training for teaching a new science curriculum and control teachers on students' outcomes in Lee's (1987) findings in the Republic of China.

Research needs to be done to improve the impact of materials and to identify specifically what inservice training is required to significantly improve the impact of materials. This is especially true for inservice in Taiwan, the Republic of China (Lee, 1987). Her study suggested little impact on student learning due to the inservice program.

Instructional Strategies

A meta-analysis which referred to innovative instructional systems was conducted by Willett and Yamashita(1983). They had 12 categories for science instruction: (1) audio-tutorial; (2) computer linked: subdivided into computer assisted , computer managed, and computer simulated experiments; (3) contracts for learning; (4) departmentalized elementary school; (5) individualized instruction; (6) mastery learning; (7) media based instruction; (8) programmed learning; (9) personalized system of instruction; (10) self-directed study; (11) use of original resource papers in the teaching of science; and (12) team teaching. They reported that the innovative instructional systems had a positive impact on students' outcomes.

Wise and Okey (1983) did a meta-analysis which investigated the effects of innovative instructional strategies in comparison with traditional strategies on students' outcomes. A highly significant category was the use of focusing techniques. Focusing occurs when students are alerted to the objective or intent of instruction before, during, or after instruction. General examples include providing students with objectives, reinforcing objectives at various points during instruction, or using advance organizers. Focusing strategies help students focus their attention on what is to be learned.

Another category created by Wise and Okey (1983) was concreteness of manipulation. Manipulative activities require students to handle, operate, or in some way work or practice with physical objects as part of the instruction process. Being involved with concrete manipulation is much more effective in producing large effects in achievement than having students observe someone else performing an experiment or merely reading about it (Hofwolt, 1985).

Wise and Okey (1983) also found increases in cognitive outcomes when inquiry-discovery strategies were used in the science classroom. Lott et al. (1983) did a study on the effects of inquiry teaching compared with inductive and deductive teaching approaches and reported positive support for inductive teaching strategies.

Many researchers have found mastery learning procedures superior to non-mastery methodologies (Bloom, 1980; Dillashaw,1983; Wise and Okey, 1983). In the classrooms, using the mastery learning approach to instruction, the material to be learned is subdivided into natural units or steps. Student performance is specified and a level at which mastery is to be attained is determined. This is called the criterion level, usually set at 80 percent (Hofwolt, 1985).

SECTION FOUR : PROBLEM SOLVING

Since the 1930's, problem solving has been emphasized as one of the major objectives in science education. In the 1980's, society has become increasingly complex. The skills of problem solving are more important than before.

Some studies (Greeno, 1978; Larkin, McDermott, Simon, & Simon 1980) proposed that the detailed specifications of problem solving strategies are of substantial importance to solving problems. Larkin et al. (1980) indicated that expert physicists perform a preliminary qualitative analysis before proposing equations for the quantitative solution of problems, in contrast, novices immediately begin the search for an equation and proceed to match the information presented in the problem with terms in the equation.

One recent trend in cognitive psychology has increasingly focused the attention of researchers on concept learning and problem solving in the science of teaching. Reif (1981) suggested a systematic approach for teaching problem solving which addressed three central questions: (1) What are the cognitive mechanisms that a student, before any instruction, tends to use in problem-solving tasks?; (2) What are the underlying cognitive mechanisms whereby such a student is theoretically expected to achieve good problem-solving performance after instruction?; and (3) By using this understanding of cognitive mechanisms underlying initial and final performance, how can one design an efficient instructional procedure whereby the student can reliably be taught to be a good problem solver?

To solve the above questions, Reif (1981) proposed that the decomposition of the problem is essential. The practical implementation of such a solution procedure requires the following prerequisites: (1) The problem solver must have an efficient strategy to search for a useful decomposition of any problem into those particular problems which he or she can readily solve; (2) Correspondingly , the problem solver's store of knowledge (or "knowledge base") must contain a judiciously selected set of solvable problems that can act as ultimate building blocks for the solution of more complex problems; and (3) The problem solver's knowledge base must be carefully organized so that selected information can be easily retrieved in diverse and complex contexts.

Reif also proposed such problem solving strategies as follows:

1. Use the method of successive refinements. It deals first with the major features of the portrait and then successively with more minor features. In scientific problem solving, such a method of successive refinements can be implemented effectively by using successively more detailed levels of description of the same situation.

2. Construct a useful initial description of the problem. Thus, a problem solver faced with a new problem must translate the problem into a form which he or she can readily understand.

3. Use systematic procedures for evaluating, and then suitably revising, any problem solution that has been obtained.

A knowledge base containing a judiciously selected set of such problem schemata is clearly very useful since it allows one to decompose any problem into the readily solvable problems provided by those schemata. A simple problem schemata may indeed be built around the application of a single important relation (e.g., a definition such as a=dv/dt, or a principle such as ma=f).

Reif et al. (1982) studied the knowledge base for mechanics and concluded that the knowledge base is constructed by the levels of conceptual schemes. These levels of concepts can be elaborated down to a level of detail which includes where small clusters of important definitions or principles in the form of precise mathematical relations. These relations are the basic knowledge components of the science of mechanics, and each of them can be elaborated further. If such a knowledge component is to be functionally useful it must be accompanied by considerable ancillary knowledge. Such ancillary knowledge includes knowledge needed to interpret concepts and relations (e.g., knowledge of procedures used to define concepts operationally, knowledge needed to achieve unambiguous specifications, and knowledge needed to make fine discriminations and avoid confusions). It also includes the knowledge of how to apply each relation to solve routinely some primitive kinds of problems (e.g., how to find any quantity in the relation from the others, how to find the change in any quantity from a change in another, and how to solve such problems quantitatively or qualitatively with various symbolic representations).

Helgeson (1987) reviewed the articles published on problem solving in middle/junior high school science education and identified implications for science teaching as follows:

1. Problem solving and science process skills are clearly related, particularly the integrated skills of identifying and controlling variables, interpreting data, defining operationally, and formulating hypotheses. Therefore it is valuable to plan for and include science process objectives in science instruction.

2. It is clear that there are differences among learners in cognitive development, cognitive styles, and learning preferences, Multiple instructional approaches provide more opportunities for these differences in learning.

3. Provide for practice in problem solving activities.

4. Include concrete representation and hands-on experiences. Few adolescents consistently operate at the formal operational level, many, in fact, reason below their capacity.

5. Use specific problem solving strategies.

6. Start with familiar variables.

7. Use science curriculum materials designed to promote inquiry and problem solving.

SECTION FIVE: DEVELOPMENT OF SCHEMATA

Two principal mechanisms for schema modification have been discussed by Rumelhart, and Ortony, (1977). Specification occurs in a schema when one or some of its variables are fixed to form a less abstract schema. Conversely, generalization occurs in a schema when some fixed portion is replaced by a variable to form a more abstract schema. For example, the typical uninstructed student has the motion schema: a push produces motion. As a result of appropriate instructional experiences, the student's motion schema could change to the following: a force produces acceleration. The fixed portion, push, in the initial schema has been replaced by a more general variable, force, which can take on several values in addition to push. Similarly, the general variable, acceleration, which can have different values has replaced the initial schema's fixed portion, motion. The modified schema is considerably more abstract and hence should have a much broader range of applicability.

The work by Chi, Feltovich, and Glaser (1981) proposed that there are differences in schemata between experts and novices: (1) The schemata of experts are based on physical principles (for example, energy conservation, Newton's second law,...etc.), but the schemata of novices are based on physical objects (for example, spring, inclined planes,....etc.) and mental constructs (for example, friction and gravity,...). (2) The contents of schemata of experts and novices do not differ significantly in information content. However, the novices' structures lack important relations, especially the relations between the surface features of the problem and the scientific principles which are the basis for solutions. (3) Experts translate the surface features of problems into canonical objects, states, and constructs. The novices represent the problem in terms of literal objects and constructs described in the text of the problem. (4) The text of the experts links representations of knowledge structures between the abstract representation of features of the problems and physical principles which are the basis for the solution of the problem. (5) Experts' schemata are organized hierarchically along the dimension of abstractness; in contrast, the different levels of the novices' knowledge are not well integrated, thus preventing easy access from one level of abstraction to another.

SECTION SIX : COGNITIVE LEARNING

A study (Anderson, Reynolds, Schallert, & Goetz, 1977) found that all incoming stimuli which are remembered are subject to reorganization by the learner. The incoming stimuli are primarily restructured by the learner in terms of the learner's own past experiences and only secondarily in terms of the organizing principles of material itself. In instructional situations, students engage in active, meaningful structuring of the text they used and the lectures they heard in order to remember and understand incoming information.

Shymansky and Yore (1980) investigated the relationship between adult students' cognitive development, teaching strategy, and resulting science achievement. They found that formal operational students were better able to cope with less structured inquiry strategies than were nonformal operational students.

A structural representation of students' knowledge before and after science instruction was studied by Champagne, and Klopfer (1981). The conceptual changes were detected between students' preinstruction representations and postinstruction representations on some geology concepts. The students' postinstruction representations were found more congruent with the content structure of the instructional materials and with the experts' knowledge structures than were their preinstruction representations. Champagne (1982) showed that there was some evidence that students whose preinstructional conceptual tasks showed good structuring made greater gains in their ability to structure geology terms than those whose preinstructional conceptual tasks showed no evidence of structuring. This observation seems to support the educational aphorism that the more you know, the more you learn.

According to the constructivist view of learning, Driver et al. (1986) have summaried six points as follows;

1. Learning outcomes depend not only the learning environment but also on the knowledge of the learner.

2. Learning involves the construction of meanings. Meanings constructed by students from what they see or hear may or may not be the intended construction of meaning which is influenced to a large extent by our existing knowledge.

3. The construction of meaning is a continuous and active process.

4. Meanings once constructed are evaluated and can be accepted or rejected.

5. Learners have the final responsibility for their learning. and

6. There are patterns in the types of meanings students construct due to shared experience with the physical world and through natural language.

SECTION SEVEN: INQUIRY LEARNING AND LABORATORY WORK

Several science educators have argued that objectives relating to the acquisition of laboratory psychomotor skills are reasonable and desirable (Klopfer, 1971; Robertson, 1985). The goals of laboratory classwork in general are considered in six types (Hegarty, 1982; Klopfer, 1971).

1. knowledge and comprehension
2. manual skills
3. processes of scientific inquiry
   a. observing and measuring

   b. interpreting data
   c. identifying problems
   d. seeking ways to solve problems
4. appreciation of ways in which scientists work
5. scientific attitude
6. application of scientific knowledge and methods.

The laboratory has long been used to develop manipulation skills and to provide experience with objects, concepts, and verification of relationships. The major function of the laboratory also provides students with opportunities to engage in the process of investigation and inquiry. Laboratory activities in the science curricula of the 1960's were supposed to be the primary vehicle for helping students solve problems, to develop attitudes toward learning and inquiry, and to think scientifically (Lunetta, 1980).

The types of laboratory have been divided into several categories: (1) verification laboratories; (2) open inquiry laboratories; (3) guided inquiry laboratories; and (4) open/guided inquiry laboratories. The verification laboratory is characterized by the traditional laboratory materials available from commercial publishers. The function of this kind of laboratory not only explains the theoretical ideas and concepts associated with the investigation but also gives the mathematical and skill background necessary to carry out the investigation and subsequent data analysis. This is usually a step by step procedure for carrying out the investigation, in order to collect the data necessary. After the data have been collected they are represented in tables or graphs for analysis and conclusions are drawn to verify the theories or concepts which were originally introduced or previously learned.

In contrast, the inquiry laboratory goes through the following sequence, students are given no theoretical background before starting the laboratory investigation, they are instructed to collect certain data, and to make sense out of the data by inventing a concept or generalization. They then are given activities which require that they use the invented concept in a new situation. This can be thought of in terms of cycle of activities corresponding to the learning cycle described by Karplus and Thier (1968) as "exploration," "invention," and "discovery."

Guided inquiry is characterized by students taking a passive role in the decisions on what data to collect and how to collect it. Open inquiry is characterized by students being able to make decisions about what the investigation should be and how to carry it out. The open /guided inquiry laboratory is the combination of the guided inquiry in "exploration" and "invention" phase and a more open-ended format in the "discovery" phase of the learning cycle.

Persons acquainted with the developmental model of learning will immediately recognize the similarities between phases of the learning cycles and the elements of the developmental model- assimilation, accommodation, and organization (Renner, 1986).

The laboratory can be a valuable setting in which students gain understanding and skills in using laboratory techniques and equipment, develop laboratory resourcefulness, learn to design experiments, prepare or select the materials needed, practice the processes of scientific inquiry in a discipline, and foster certain problem-solving abilities and scientific attitudes. Anderson and others (1983) presented data from several hundred studies that indicated that for most learning outcomes, hands-on activities helped to improve learning. The studies did not identify that types of laboratories were most effective.

SECTION EIGHT : STUDIES ON HEAT AND TEMPERATURE

The concepts of heat and temperature are the basis for thermodynamics and play an important role in other areas of physics (e.g., conservation of energy, theories of matter) as well as chemistry (e.g., endothermic and exothermic reaction) and biology (e.g., metabolism) (Wiser, 1988). Unfortunately, these concepts are very difficult for students to master. Alternative frameworks which were different from theory to be learned, were found in the students' pre-existing knowledge about that domain. Those alternative frameworks are difficult to displace. First, students may be unwilling to give them up because of their familiarity and intuitive appeal, attributes generally lacking in textbook theories (Posner, Strike, Heweson and gertzog, 1982). Second, students may not even understand the textbook theories, because the concepts, rules, and explanatory schemata they use to interpret the textbook statements are inappropriate.

The study of Wiser et al. (1988) identified several difficulties with which students should be helped in learning these topics as follows:

1. The key concept students lack, and have great difficulty acquiring, is amount of heat, an extensive variable.

2. In real experiments, heat transfer is not so easy to control as temperature and cannot be dissociated from it.

3. Concepts of heat and temperature are not easy to differentiate.

4. Students found it difficult to master applying thermal equilibrium states under which heat is exchanged (the

students' conceptualization has no need to account for heat exchanges:sources emit heat spontaneously).

Albert (1978) found that there existed certain patterns of development of concepts of heat and temperature in its logical sequences (the concrete reasoning, the early formal reasoning, and formal reasoning). In his perspective, the environment is seen as nourishing the cognitive domain of the living organism. The concepts are generated in the process of interaction of the human organism with his environment.

The method of interviewing students about their reasoning has been used as a way of understanding the student cognitive structure (Erickson, 1979). By using interview techniques, naturalistic information was collected on understanding on heat concepts among students of different age groups. The development of the concepts of heat and temperature has been found to differ with children of different ages. Erickson et al. (1980) studied student viewpoints on heat for a sample of fifth grade, seventh grade, and ninth grade students. They found that a relatively high proportion of students had intuitive ideas about heat. It appeared that the children's viewpoints about heat were not confined to a small proportion of 12-year-old children.

Engel Clough and Driver (1985) noted that the early introduction of kinetic theory into the secondary science curriculum had little influence on the understanding of other physics concepts, including heat. Students tend not to use kinetic theory in explanations of phenomena concerning heat. The evidence strongly suggested (Engel Clough et al. 1985) that many ideas about heat previously associated with the thinking of young children remain with secondary school students up to the age of 16 and older, and that all were built upon a fund of experiential knowledge about heat from early age.

Summers (1983) evaluated some school texts and found that using the definition of heat in different ways made a difference in student concepts of heat and resulted in more learning related to heat.

Recently, Rogan (1988) found a significant difference between two instructional strategies in teaching concepts of heat to ninth grade students. It was based on the theory of conceptual change proposed by Hewson (1981) and Posner, Strike, Hewson, and Gertzog (1982). The sequence of lessons was designed to have two crucial points. The first of these occurs in the second lesson. The question is posed, "what is heat?" "What actually goes on inside an object as it is heated?" The teacher was asked to guide a discussion in which the various viewpoints of heat were raised and articulated. The second crucial point occurred during the last lesson. The various phenomena observed were reviewed in terms of the ability of the two theories to provide adequate explanations. Some new phenomena, such as heat from friction, which cannot readily be explained by the caloric theory, were introduced and discussed at this point. In the other teaching strategy, called the single-theory approach, only answers reflecting kinetic viewpoints were accepted, and only the kinetic theory was articulated. Both approaches covered the same content areas in a fourteen-lesson sequence. With a summary of the results obtained by using (a) both the kinetic and caloric theories (b) only the kinetic theory, students in both instructional approaches showed similar gains in their allegiance to the kinetic theory of heat. The low-reasoning students, in particular, appeared to benefit from the conceptual-change approach. They showed a significant decrease in their belief in the caloric theory compared to low-reasoning students who were exposed to the kinetic theory only. Reasoning skills were found more effective for learning the concepts of heat.

A number of studies revealed that the development of scientific concepts is significantly related to Piagetian stages (Lawson, 1985; Renner, 1979; Shayer, 1979; Staver, 1984). Shayer and Wylan (1981) have reported that student development of concepts in the area of heat is largely determined by the powers and limitation of the concrete operational thinking which is the main developmental phase present in the age- group.

The findings presented related to heat and temperature strongly supported Erickson's recommendation for further educational research that would make a significant contribution to classroom practice including:

1. Limit required reasoning about concepts at particular grade or age levels;

2. Develop instructional sequences suitable to a broad spectrum of students; and

3. Provide strategies for assisting students with certain types of misconceptions.

CHAPTER III

METHODS AND PROCEDURES

This chapter includes six sections. The first section describes the population and sample. The second section describes the development of the instructional model and materials. The third section describes the instruments and instrument development. The fourth section describes the treatment. The fifth section describes the collection of data. The sixth section relates to data analyses.

SECTION ONE: POPULATION AND SAMPLE

Population

The population was comprised of eighth grade students in four types of schools in Taiwan, Republic of China. The four types of schools from which schools were selected were:

1. highly selective schools in cities;
2. urban schools;
3. suburban schools; and
4. town and country schools.

Schools were not selected from the rural areas.

Sample

Four schools were selected from the four main types of schools. One school was selected randomly from each type of school. Two classes (one experimental and one control) were randomly selected from the highly selective school, four classes (two experimental and two control) were randomly selected from the urban school, two classes (one experimental and one control) were randomly selected from the suburban school, and four classes (two experimental and two control) were randomly selected from the school that was a mixture of students from a town and the country. About 75 percent of the selected classes were located in urban and suburban areas (approximately 66 percent of population lives in urban areas in the Republic of China, The World Book Encyclopedia, 1984). Six teachers taught the experimental classes and six different teachers taught the control classes. The number of students in the experimental group was 277; the number of students in the control group was 260.

SECTION TWO: THE DEVELOPMENT OF MODEL AND MATERIALS

The Development of the CAG Model

Based on the findings of literature review in Chapter II, it was decided to construct the conceptual ideas in terms of schemata in the cognitive mechanism of the individuals. Some individuals may have undeveloped schemata related to some science concepts and some may be developing schemata in terms of the science concepts. Some of them may have developed schemata of the science concepts being studied. Frequently, the analysis of a pretest before instruction can help an instructor to understand the levels of the schemata which the students have in terms of the science concepts. Good instructional materials and strategies provide students with the possibilities to develop their schemata from an undeveloped stage to a developed stage and to move from one conceptual level to another conceptual level in appropriate sequences.

Based on Piagetian theory, an effective instructional strategy is a learning cycle which moves from the exploration phase through the invention phase to the expansion phase. Pella's (1975) concept of concept model emphasizes that learning should move from low levels to high levels in a three dimensional space which consists of the dimensions of sophistication, abstractness, and complexity (see Chapter I). By combining both Piagetian theory and Pella's concept of concept ideas, materials can be developed to help a learner to move from an undeveloped stage through the developing stage to the developed stage and from a low level concept understanding to a high level concept understanding.

The CAG (Correlation, Analysis, and Generalization) model consists of five steps which include one step of correlation and two cycles of analysis and generalization. The diagram in Figure 3.1 describes the CAG model. The first step is to correlate the learned concepts to form a new concept. For instance, the change of mass of a sample under discussion and its change in temperature can be correlated to the heat energy introduced or removed from a sample. By dealing with the correlations of prior concepts, a new concept can be developed as the schema in a learner. The second step and the third step are the first cycles of analysis and generalization. In the second step the method of analysis or differentiation is used to move the concepts from the descriptive type through the comparative type to the quantitative type. In this step a learner's schemata on the concepts can be developed in multiple facets. The third step is the process of integration. The concepts acquired from the second step are integrated or generalized based on their commonality. A simple generalization of the concept should be drawn.

Concrete laboratory tasks are appropriately used in the learning cycle. The schemata can be developed more effectively if the activities are based on learner's concrete experiences. The first three parts of the CAG learning cycle are very similar to the exploration and invention phases in the Piagetian learning cycle.

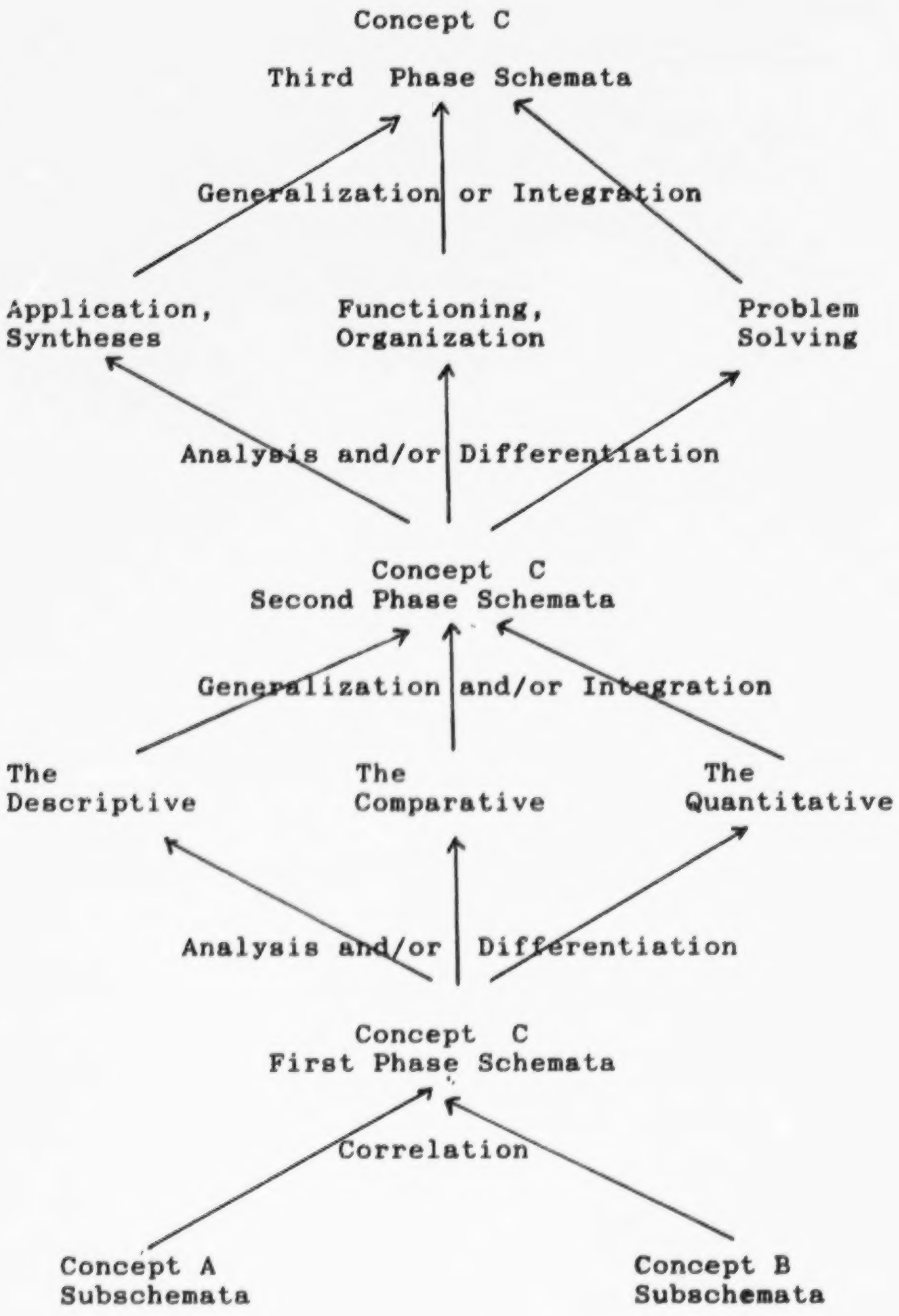

Concept C
Third Phase Schemata
Generalization or Integration
Application, Syntheses
Functioning, Organization
Problem Solving
Analysis and/or Differentiation
Concept C
Second Phase Schemata
Generalization and/or Integration
The Descriptive
The Comparative
The Quantitative
Analysis and/or Differentiation
Concept C
First Phase Schemata
Correlation
Concept A Subschemata
Concept B Subschemata

Figure 3.1 The CAG Model

The fourth step and fifth step in the CAG learning cycle are the second cycle of analysis and generalization. In the fourth step, more complicated natural phenomena are related to the concept and are analyzed related to a theme, a big idea, or a problem. In this step the learner's schemata related to the concepts can be developed more than before so that it can deal with more complicated natural phenomena. The fifth step is a higher order of generalization or integration. Combining the commonality among the themes, big ideas, or problems helps students to be able to generalize the ideas.

In this part of the cycle, discussion and lecture are appropriately used. It is important to provide students opportunities to organize their learning more effectively based on the organizers related to the concepts. This cycle tends to push the learner's schemata in a systematic and scientific way.

The Development of the CAG Module

Based on the content area of the New Physical Science Curriculum (NPSC, 1988) a unit on temperature, heat, heat transfer, and specific heat was developed based on the CAG model. Hands-on-activities and work sheets were developed for laboratory work to focus student attention on the tasks.

The CAG module was developed with eight parts. Most of the contents were selected from physical science curricula or text books (Burkman, et al., 1981; Williams, et al., 1979; Ewen, et al., 1988; Brandwein, et al., 1980; See Appendix C). Part of the contents were developed by the researcher. The eight parts of the CAG module in order are as follows:

1. Building a heat measure,
2. Temperature,
3. Heat,
4. Heat transfer,
5. Specific heat,
6. Method of mixtures,
7. Measurement of specific heat of an unknown metal, and
8. Reviewing the concepts for the module.

Part 1, 'Building a thermometer ' is a concrete task for constructing a thermometer. According to the set of activities, the relationships between the change of properties of a substance and its change of temperature are correlated. It also helps students to develop their schemata on the concept of temperature as a descriptive concept, a comparative concept, and a quantitative concept. The instructor plays a major role leading discussion related to data to develop the simple generalization of temperature for the learners.

The second cycle of analysis and generalization is based on the sections titled as follows:

1. Relationships between the degree of temperature and the color of light given off.
2. Temperature is a measure of average kinetic energy.
3. What happens when an object takes in heat
4. The exchange of temperature scales.

In the second part, the concept of temperature is developed to relate to more complicated natural phenomena. It provides more detail in the analysis of the natural phenomena under the organizers and the scientific concept of temperature is used in applications, and problem solving. In this cycle instructional materials play the major role to help students to generalize the ideas into scientific concepts.

Some exercises are given at the end of each section that can provide the opportunities for learners to elaborate their schemata more effectively.

Part 3 develops the concepts of heat. The correlation of the amount of a substance and its temperature change to its thermal energy changed is presented first.

The first cycle of the analysis and generalization is "Getting into hot water." Students are required to do the activities and answer the questions in the activities. The instructor is involved in the activities to assist and to conduct discussions based on the data collected by the students to develop a simple generalization of the concept of heat.

The second cycle of the analysis and generalization is focused on the sections titled as follows;

1. What is a calorie?
2. Heat is made up of internal energies.
3. Heat and work.

The instructional materials play a major role in helping students to analyze in more detail the concept as it relates to natural phenomena and to generalize the concept of heat.

Part 4 is related to heat transfer. Conduction, convection, and radiation are correlated to the movement of heat. In the first cycle, each type of heat movement is analyzed and a simple generalization for heat transfer is developed. The second cycle of analysis and generalization is developed under the sections titled as follows:

1. Controlling the transfer of heat
2. Solar heating.

More details of the natural phenomena are involved in the organizers. Students are helped to develop a generalization of the direction of heat transfer.

Parts five, six, and seven are related to the topic of specific heat. Part five deals with the correlation among the variables of specific heat, heat change, temperature change, and properties of substance. In order to be familiar with these relationships several concrete examples are provided, and a table of thermal constants such as specific heat, boiling points, and melting points, is provided in the instructional material.

Part six provides examples of thermal contact, e.g., the method of mixture. This part relates to the first cycle of analysis and generalization on specific heat. The task moves the concept of specific heat from the descriptive type through the comparative type to the quantitative type. The problem-solving examples are designed to generalize the concept of specific heat.

Part seven is related to the second cycle of analysis and generalization of the concept of specific heat. The measurement of specific heat for an unknown metal is involved in the activities. Several questions are required to be answered through investigations. The learner should develop an ability to generalize his learning more effectively.

Part eight is the summary of the important concepts for this module.

The teaching strategies for teaching heat are selected by applying the CAG module as indicated in Figure 3.2.

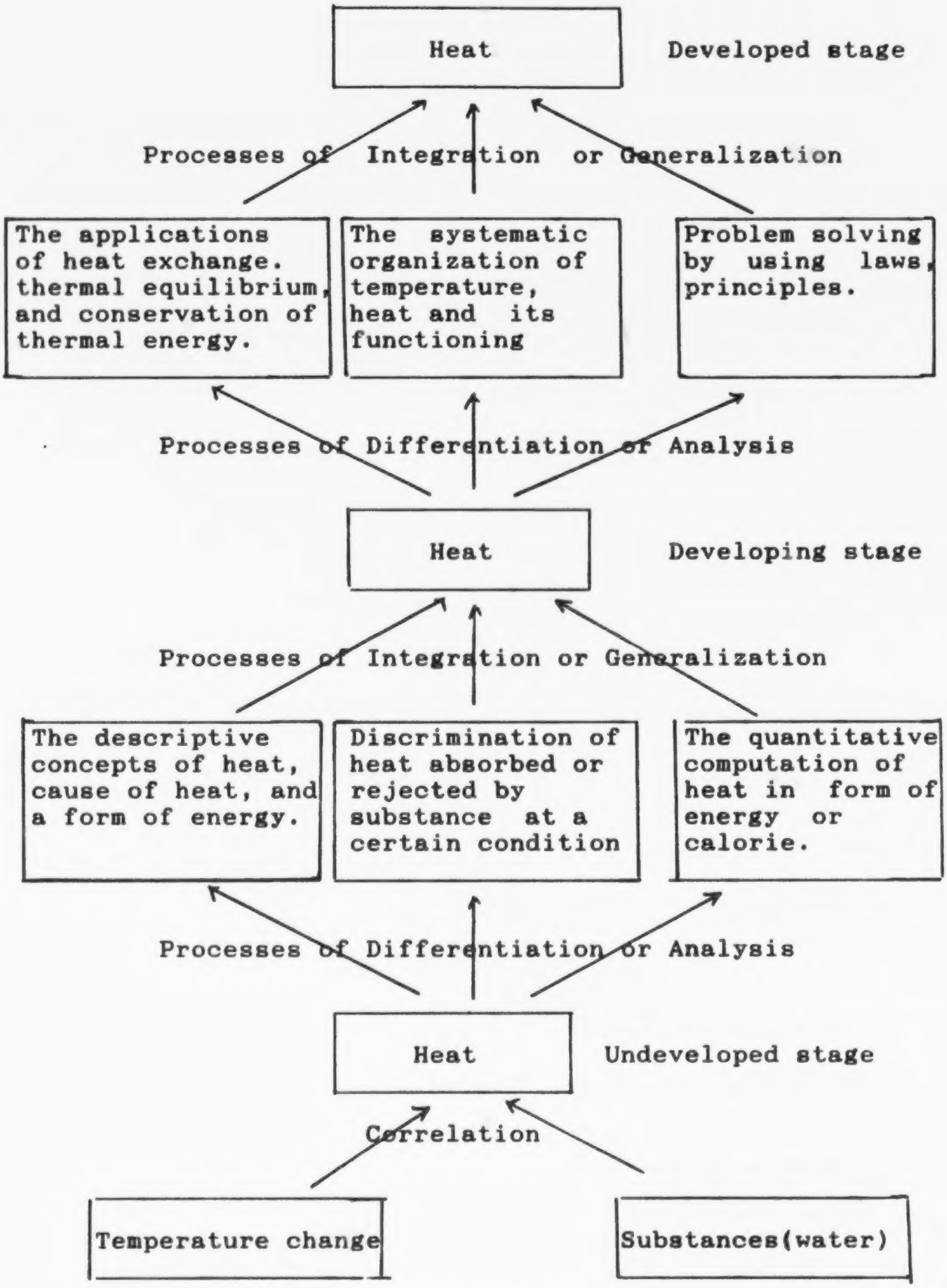

Heat
Developed stage
Processes of Integration or Generalization
The applications of heat exchange. thermal equilibrium, and conservation of thermal energy.
The systematic organization of temperature, heat and its functioning
Problem solving by using laws, principles.
Processes of Differentiation or Analysis
Heat
Developing stage
Processes of Integration or Generalization
The descriptive concepts of heat, cause of heat, and a form of energy.
Discrimination of heat absorbed or rejected by substance at a certain condition
The quantitative computation of heat in form of energy or calorie.
Processes of Differentiation or Analysis
Heat
Undeveloped stage
Correlation
Temperature change
Substances(water)

Figure 3.2. The CAG Model for Teaching Heat

SECTION THREE: THE DEVELOPMENT OF THE INSTRUMENTS

Several instruments were used in this study. Each instrument is described.

The Pretest

The pretest was developed by the investigator and had three parts: (1) prior knowledge; (2) mathematical knowledge; and (3) Piagetian tasks. Prior knowledge assessed consisted of major concepts of temperature and heat which the students should have learned before grade eight. Mathematical knowledge included number concepts, skills of equation solving, and graphic skills that were required to learn the unit. The Piagetian tasks consisted of proportional reasoning, combinatorial reasoning, and propositional reasoning. These skills were the reasoning skills needed to learn the materials presented. The pretest is included in Appendix A.

Analysis of the Pretest

Three parts of the pretest are follows:

1. Prior knowledge.
    a. Item distribution

The pretest contained 19 prior knowledge items. Table 3.1 presents the distribution of the prior knowledge items of the pretest across item difficulty, the Piagetian levels, and the content areas. No items were included at the formal level on the Piagetian reasoning.

Table 3.2, Table 3.3, Table 3.4, and Table 3.5 present the distribution of prior knowledge items of temperature, heat, heat transfer, and specific heat across concept domain, process skills, and the Piagetian levels among the sections of the CAG module.

b. Item difficulty.

Table 3.6 presents the average item difficulty of the content areas across the Piagetian logical reasoning levels. The overall average item difficulty of the prior knowledge was .51. The average item difficulty at both the concrete level and the transitional level was .51. Some items identified at the concrete level, such as items 16 and 17 of the prior knowledge, scored low(see Table 3.1). Students did not have a good understanding of several simple concepts before instruction.

The average item difficulties calculated by content areas were .56, .54, .53, and .42 corresponding to temperature, heat, specific heat, and heat transfer, respectively. See Table 3.6.

c. Test reliability

The reliability (KR- 20) of the prior knowledge test was .58 based on the sample of this study. Since the test assessed several concepts and student understanding varied, the reliability in this case is about what the researcher expected.

Table 3.1 The Analysis of Items of Pretest across Item Difficulty, Piagetian Reasoning Levels in the Content Areas.

No.	Item Diff.		Content Area Category				Piagetian Level Reasoning			
	Mean (N=537)	S.D.	TEMP. & THER.	HEAT	SPEC. HEAT	HEAT TRANS.	Type	C.	TR.	F.
1	.55	.50	*				Corr.		*	
2	.40	.49	*				Propor.	*		
3	.57	.45		*		*	Corr.		*	
4	.42	.49		*			Corr.		*	
5	.71	.46	*	*			Corr.	*		
6	.35	.48	*				Corr.		*	
7	.60	.49				*	Corr.	*		
8	.59	.49				*	Corr.	*		
9	.71	.46	*	*			Proposi.		*	
10	.82	.39		*			Corr.	*		
11	.45	.50				*	Corr.	*		
12	.41	.49			*		Propor.		*	
13	.67	.46		*			Proposi.	*		
14	.65	.48			*		Proposi.		*	
15	.40	.49		*			Proposi.		*	
16	.18	.39		*			Corr.	*		
17	.14	.35				*	Corr.	*		
18	.25	.43				*	Corr.	*		
19	.79	.37	*				Corr.	*		
Overall	.51		6	8	2	6		11	8	0

C is the concrete level.
TR. is the transitional level.
F is the formal operational level.

Table 3.2. The Analysis of Items of Temperature and Thermometer in the Pretest across Concept Domain, Process Skills, and Piagetian Reasoning Levels in the Content Areas.

	Concept Domain					Process Skills			Piagetian Level			
QUE. NO.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
1	* (13. 1-1)								Corr.		*	
2			* (13. 1-4)						Propor.	*		
5				* (Act. 13, 14; 13. 1-3)					Corr.	*		
6		* (Act. 13; 13. 1-2)							Corr.		*	
9		* (13. 1-2)							Proposi.		*	
19		* (Act. 13)				Measuring	*		Corr.	*		
Cum. item	1	3	1	1	0		1			3	3	0

DES.: the descriptive concept. CMP.: the comparative concept. QUA.: the quantitative concept. APP.: application. PRO. : problem solving. L : low level.
H : high level. C : the concrete level.
TR: the the transitional level.
F : the formal operational level.
Act. : the activity on the CAG module.
Propor.: proportional reasoning.
Corr.: correlational reasoning.
Proposi.: propositional reasoning.

Table 3.3. The Analysis of Items of Heat in the Pretest across Concept Domain, Process Skills, and Piagetian Reasoning Levels in the Content Areas.

	Cognitive Domain					Piagetian	Logic		
	Concept Type					Reasoning Type	Level		
QUE. NO.	DES.	CMP.	QUA.	APP.	PRO.		C.	TR.	F.
3				* (Act. 14; 13. 3-2)		Corr.		*	
4			* (13. 2-2)			Corr.		*	
5				* (Act. 13, 14)		Corr.	*		
9		* (13. 2-3; 13. 5-1)				Proposi.		*	
10	* (13. 2-3; 13. 1-2)					Corr.	*		
13			* (13. 2-3)			Proposi.	*		
15			* (Act. 14)			Proposi.		*	
16	* (Act. 14)					Corr.	*		
Cum. item	2	1	3	2	0		4	4	0

DES.: the descriptive concept. CMP.: the comparative concept. QUA.: the quantitative concept. APP.: application.
PRO. : problem solving. L : low level.
H : high level. C : the concrete level.
TR. : the the transitional level.
F : the formal operational level.
Act. : the activity on the CAG module.
Corr.: correlational reasoning.
Proposi.: propositional reasoning.

Table 3.4. The Analysis of Items of Specific Heat in the Pretest across Concept Domain, Process Skills, and Piagetian Reasoning Levels in the Content Areas.

Concept	Domain					Piagetian	Level		
QUE. NO.	DES.	CMP.	QUA.	APP.	PRO.	Reasoning Type	C.	TR.	F.
12		* (13. 4-1)				Propor.		*	
14	* (Act. 15)					Proposi.		*	
Cum. item	1	1	0	0	0		0	2	0

DES.: the descriptive concept. CMP.: the comparative concept. QUA.:the quantitative concept. APP.: application.
PRO. : problem solving. L : low level.
H : high level. C : the concrete level.
TR. : the the transitional level.
F : the formal operational level.
Act. : the activity on the CAG module.
Propor.: proportional reasoning.
Proposi.: propositional reasoning.

Table 3.5. The Analysis of Items of Heat Transfer in the Pretest across Concept Domain, Process Skills, and Piagetian Reasoning Levels in the Content Areas.

	Concept	Domain				Piagetian Level			
QUE. NO.	DES.	CMP.	QUA.	APP.	PRO.	Reasoning Type	C.	TR.	F.
3				* (13. 3-1, 13. 3-2)		Corr.		*	
7				* (13. 3-1)		Corr.	*		
8				* (13. 3-2)		Corr.	*		
11	* (13. 3-1)					Corr.	*		
17	* (13. 3-1)					Corr.	*		
18	* (13. 3-1)					Corr.	*		
Cum. item	3	0	0	3	0		5	1	0

DES.: the descriptive concept. CMP.: the comparative concept. QUA.:the quantitative concept. APP.:application.
PRO.: problem solving. L: low level.
H : high level. C : the concrete level.
TR. : the the transitional level.
F : the formal operational level.
Act. : the activity on the CAG module.
Propor.: proportional reasoning.
Corr.: correlational reasoning.
Proposi.: propositional reasoning.

Table 3.6 The Analysis of Average Item Difficulty of the Pretest in the the Content Areas across the Piagetian Logic Reasoning Levels.

Content Area	Piagetian Levels								
	Concrete			Transitional			Overall		
	I.D.	S.D.	I.W.	I.D.	S.D.	I.W.	I.D.	S.D.	I.W.
Temperature	.62	.29	2.5	.50	.29	2.5	.56	.22	5.0
Heat	.58	.26	3.5	.49	.11	3.0	.54	.21	6.5
Specific heat	.	...	...	.53	.34	2.0	.53	.34	2.0
Heat tran.	.40	.23	5.0	.57	.50	.5	.42	.22	5.5
Overall	.51			.51			.51		

I. D. : Average item difficulty.
I. W. : Item weight. If an item was related to one category of content area it accounted for 1.0 of weight for this category. Consider an item was related to two categories in content areas. The weight of this item for each category was accounted .5. (For instance, item 3 was related to categories of heat and heat transfer, then item 3 was accounted .5 for its weight in each category of heat and heat transfer, respectively. See Table 3.1).

2. Mathematics Skills.

The pretest contained 12 mathematics skill items. Table 3.7 presents the distribution of items across item difficulties, concept categories, and the Piagetian levels.

The overall average item difficulty of the mathematics skills was .62. Item difficulties averaged .82, .77, and .28 at the concrete level, transitional level, and formal level, respectively.

The reliability (KR-20) of the mathematics skill test was .71 based on the sample of this study. The reliability was about what was expected based on the design of the test.

Table 3.7 The Analysis of Mathematics Items in the Pretest across the Piagetian Logical Thinking.

NO.	Item Diff.(N=537)			Piagetian	levels		
	Mean	S.D.	Category	Reasoning Type	C.	TR.	F.
1	.99	.10	A set of number	Propor.	*		
2	.68	.47	A set of number	Propor.	*		
3	.68	.47	A set of number	Propor.		*	
4	.80	.28	A set of number	propor.		*	
5	.73	.44	Equation solving	Corr.	*		
6	.86	.35	Equation solving	Corr.	*		
7	.83	.38	Equation solving	Corr.		*	
8	.78	.41	Equation solving	Corr.		*	
9	.21	.41	Equation formulation	Propor & proposi.			*
10	.38	.49	Equation solving	Proposi.			*
11	.26	.44	Data interpreting	Controlling variable			*
12	.28	.45	Data interpreting	Controlling variable			*
Overall	.62				4	4	4

C : the concrete level.
TR. : the transitional level.
F : the formal level.
Propor.: proportional reasoning.
Corr.: correlational reasoning.
Proposi.: propositional reasoning.

3. Piagetian Tasks

There were eight Piagetian items in the pretest. Table

3.8 presents the distribution of items of the Piagetian tasks across its reasoning levels.

The overall average item difficulty of the Piagetian tasks was .68. Item difficulties averaged .99, .81, and .33 at the concrete level, the transitional level, and the formal level, respectively.

The reliability (KR-20) of the Piagetian tasks was .55 based on the sample of the study. This was about the reliability anticipated for this test based on the number of items and due to the high scores on concrete and transitional levels and low scores at the formal level.

4. Test Reliability of the Pretest

The reliability (KR-20) of the overall pretest was .74 based on the sample of this study.

Table 3.8 The Analysis of Items of Piagetian Logical Reasoning in the Pretest.

NO.	Item Diff. Mean	S.D.(537)	Reasoning Type	Reasoning Level C.	TR.	F.
1	.99	.09	Proportional	*		
2	.71	.45	Proportional		*	
3	.55	.50	Proportional			*
4	.99	.12	Propositional	*		
5	.94	.24	Propositional		*	
6	.13	.32	Propositional			*
7	.80	.39	Combinatorial		*	
8	.30	.34	Combinatorial & Controlling variables			*
Overall	.68			2	3	3

C : the concrete level. TR. : the transitional level.
F : the formal operational level.

Analysis of the Posttest and Follow-up Test

Three parts are presented as follows:

1. The Item Distribution;

There were 40 questions contained in the posttest. The items of the posttest and the follow-up test were the same. The items of prior knowledge in the pretest were included in the posttest and the follow-up test.

The posttest is included in Appendix B.

Table 3.9 presents the distribution of the items of the posttest across the Piagetian levels and the content areas.

Table 3.10 presents the comparison of the item difficulty between the experimental group and the control group. The average item difficulty for the experimental group was .61 with a standard deviation .16. The average item difficulty for control group was .55 with a standard deviation .17.

Tables 3.11, 3.12, 3.13, and 3.14 present the distribution of posttest items related to the concept domain, the process skills, and the Piagetian levels among the sections of the CAG module.

Table 3.15 presents the average item difficulty of the content areas of the posttest across the Piagetian reasoning levels. The overall average item difficulty of the posttest was .58 based on the total sample of this study. There were item difficulties of .74, .63, and .28 at the concrete level, the transitional level, and the formal level, respectively.

2. Test Validity of the Posttest;

The items developed were based on the content of NPSC and used in the pilot test. Items of the pilot test were analyzed for difficulty and for discrimination. As a result, some items in the pilot revision were dropped, some items were modified, and some new items were added to form the posttest. The posttest was reviewed by both American and Chinese science educators and was judged to have good content validity as it related to the treatment and control curricula.

3. Test Reliability;

The reliability (KR-20) of the instrument in the pilot test was .79. The reliability of the final form was .88 for the instrument when used as a posttest, and .90 when used in a follow-up test. This pattern was expected since those who scored higher after the instruction had more correct responses to items.

Table 3.9 The Analysis of Items of Posttest across Item Difficulty, Piagetian Reasoning Levels, and Content Areas.

No.	Item Diff. (537)		Content Areas				Piagetian Level			
	Mean	S.D.	TEMP. & THER.	HEAT	SPEC. HEAT	HEAT TRANS.	Reasoning Type	C	TR.	F.
1	.61	.49	*				Corr.		*	
2	.67	.47	*				Propor.	*		
3	.78	.41		*		*	Corr.		*	
4	.53	.50		*			Corr.		*	
5	.89	.31	*	*			Corr.	*		
6	.48	.50	*				Corr.		*	
7	.73	.44				*	Corr.	*		
8	.83	.37				*	Corr.	*		
9	.79	.41	*	*			Proposi.		*	
10	.87	.34		*			Corr.	*		
11	.65	.48				*	Corr.	*		
12	.53	.50			*		Propor.		*	
13	.78	.41		*			Proposi.	*		
14	.75	.43			*		Proposi.		*	
15	.16	.37	*				Corr.			*
16	.46	.50	*				Propor.			*
17	.74	.44		*			Propor.		*	
18	.52	.50		*		*	Corr.		*	
19	.61	.49		*	*		Propor.			*
20	.60	.49		*			Corr.		*	
21	.80	.40		*			Proposi.		*	

Continue

TEM. & THE.: Content on temperature and thermometer.
SPEC. HEAT : Content on specific heat.
HEAT TRANS.: Content on heat transfer.
Item Diff. : Item difficulty.
C is the concrete level.
TR. is the transitional level.
F is the formal operational level.

Table 3.9. (continue)

No.	Item Diff.(N=537)		Content	Areas			Piagetian	Level		
	Mean	S.D.	& TEMP. THER.	HEAT	SPEC. HEAT	HEAT TRANS.	REASONING TYPE	C	TR.	F.
22	.56	.50		*			Propor.		*	
23	.49	.49		*			Proposi.			*
24	.18	.28		*	*	*	Corr.			*
25	.59	.50			*		Proposi.		*	
26	.45	.46			*		Corr.		*	
27	.21	.41			*		Proposi.			*
28	.76	.43		*			Corr.	*		
29	.59	.50				*	Corr.	*		
30	.77	.42				*	Corr.	*		
31	.70	.40	*				Proposi.	*		
32	.82	.30				*	Corr.	*		
33	.71	.35				*	Corr.		*	
34	.16	.37		*			Proposi.			*
35	.10	.31			*		Corr.			*
36	.38	.49		*			Proposi.			*
37	.89	.32	*				Corr.	*		
38	.54	.50			*		Corr.	*		
39	.01	.10	*				Corr.			*
40	.58	.50			*		Corr.	*		
Overall	.58		10	17	10	10		15	15	10

Table 3.10 The Item Difficulty of the Posttest across Groups.

NO.	Item Diff. for Exp. (N=277)		Item Diff. for Control (N=260)		NO.	Item Diff. for Exp. (N=277)		Item Diff. for Control (N=260)	
	Mean	S.D.	Mean	S.D.		Mean	S.D.	Mean	S.D.
1	.64	.48	.58	.50	21	.83	.37	.76	.43
2	.68	.47	.66	.48	22	.64	.48	.49	.50
3	.81	.39	.75	.43	23	.55	.46	.43	.46
4	.56	.50	.51	.50	24	.19	.29	.15	.25
5	.92	.27	.86	.35	25	.59	.49	.59	.49
6	.49	.50	.50	.50	26	.56	.46	.34	.43
7	.72	.45	.75	.43	27	.26	.44	.15	.36
8	.83	.38	.84	.37	28	.77	.42	.74	.44
9	.81	.40	.77	.42	29	.60	.49	.57	.50
10	.94	.23	.80	.40	30	.82	.39	.72	.45
11	.70	.46	.59	.50	31	.76	.36	.63	.42
12	.55	.50	.52	.50	32	.84	.26	.79	.34
13	.84	.37	.72	.45	33	.81	.28	.62	.38
14	.77	.43	.74	.44	34	.22	.42	.10	.30
15	.17	.37	.15	.36	35	.15	.36	.05	.23
16	.47	.50	.46	.50	36	.45	.50	.30	.46
17	.77	.42	.70	.46	37	.92	.24	.81	.37
18	.56	.50	.49	.50	38	.52	.50	.57	.50
19	.59	.49	.63	.48	39	.01	.10	.01	.09
20	.68	.47	.51	.50	40	.60	.49	.57	.50

Exp.: The experimental group.
Control: The control group.

Table 3.11. The Analysis of Items of Temperature and Thermometer in the Posttest across Concept Domain, Process Skills, and Piagetian Reasoning Levels.

	Concept Domain					Process Skills			Piagetian Level			
Que. No.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
1	* (13. 1-1)								Corr.		*	
2			* (13. 1-4)						Propor.	*		
5				* (Act. 13, 14; 13. 1-3)					Corr.	*		
6		* (Act. 13; 13. 1-2)							Corr.		*	
9		* (13. 1-2)							Proposi.		*	
15	* (13. 1-1)								Corr.			*
16		* (13. 1-4)				Interpreting data		*	Propor.			*
31				* (13.1-3)		Formulating Hypothesis	*		Proposi.	*		
37		* (Act. 13)				Measuring	*		Corr.	*		
39		* (13. 1-2)							Corr.			*
Cum. item	2	5	1	2	0		2	1		4	3	3

DES.: the descriptive concept. CMP.: the comparative concept. QUA.: the quantitative concept. APP.: application.
PRO. : problem solving. L : low level.
H : high level. C : the concrete level.
TR. : the the transitional level.
F : the formal operational level.
Act. : the activity on the CAG module.

Table 3.12. The Analysis of Items of Heat in the Posttest across Concept Domain, Process Skills, and Piagetian Reasoning Levels.

Concept Domain						Process			Piagetian Level			
Que. No.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
3				* (Act. 14; 13. 3-2)					Corr.		*	
4			* (13. 2-2)						Corr.		*	
5				* (Act. 13, 14)					Corr.	*		
9		* (13. 2-3, 13. 5-1)							Proposi.		*	
10	* (13. 2-3, 13. 1-2)								Corr.	*		
13			* (13. 2-3)						Proposi.	*		
17			* (Act. 13, 14)			Interpreting		*	Proposi.		*	
18				* (Act. 14)					Corr.		*	
19					* (13. 4-1)				Propor.			*
20	* (Act. 14)								Corr.		*	
21			* (Act. 14)						Proposi.		*	

Continue

Table 3.12 (continue)

	Concept	Domain				Process			Piagetian	Level		
Que. No.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
22			* (Act. 14)						Propor.		*	
23					* (Act. 14; 13. 5-1)				Proposi.			*
24					* (Act. 14, 15; 13.3-1, 13. 4-1. 13. 5-1)	Controlling Vari.		*	Proposi.			*
28	* (Act. 14)								Corr.	*		
34					* (Act. 14, 13. 1-4)				Proposi.			*
36					* (Act. 14, 13. 5-1)				Proposi.			*
Cum. Item	3	1	5	3	5		0	2		4	8	5

DES.: the descriptive concept. CMP.: the comparative concept. QUA.: the quantitative concept. APP.: application.
PRO. : problem solving. L : low level.
H : high level. C : the concrete level.
TR. : the transitional level.
F : the formal operational level.
Act. : the activity on the CAG module.
Propor.: proportional reasoning.
Corr.: correlational reasoning.
Proposi.: propositional reasoning.

Table 3.13. The Analysis of Items of Specific Heat in the Posttest across Concept Domain, Process Skills, and Piagetian Reasoning Levels.

Concept	Domain				Process				Piagetian	Level		
Que. No.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
12		* (13. 4-1)							Propor.		*	
14	* (Act. 15)								Proposi.		*	
19					* (13. 4-1)				Propor		*	
24					* (Act.14, 15; 13.3-1, 13.4-1, 13. 5-1)	Measuring		*	Corr.			*
25		* (13. 4-1)				Interptreting data		*	Proposi.		*	
26			* (13. 4-1)						Corr.		*	
27					* (13. 4-1, 13. 5-1)				Proposi.			*
35					* (13. 4-1, 13. 5-1)				Corr.			*
38		* (13. 4-1)							Corr.	*		
40		* (Act.15)							Corr.	*		
Cum. item	1	4	1	0	4		0	2		2	5	3

DES.: the descriptive concept. CMP.: the comparative concept. QUA.: the quantitative concept.
App.: Application.
PRO.: problem solving. L:low level. H: high level. C: the concrete level.
TR. : the transitional level.
F : the formal operational level.
Act. : the activity on the CAG module.

Table 3.14. The Analysis of the Items of Heat Transfer in the Posttest across Concept Domain, Process Skills, and Piagetian Reasoning Levels.

	Concept Domain					Piagetian Level			
Que. No.	DES.	CMP.	QUA.	APP.	PRO.	Reasoning Type	C.	TR.	F.
3				* (13. 3-1, 13. 3-2)		Corr.		*	
7				* (13. 3-1)		Corr.	*		
8				* (13. 3-2)		Corr.	*		
11	* (13. 3-1)					Corr.	*		
18				* (13. 3-1, 13. 3-2)		Corr.		*	
24					* (13. 3-1)	Corr.			*
29	* (13. 3-1)					Corr.	*		
30	* (13. 3-1)					Corr.	*		
32				* (13. 3-2)		Corr.	*		
33				* (13. 3-2)		Corr.		*	
Cum. item	3	0	0	6	1		6	3	1

DES.: the descriptive concept. CMP.: the comparative concept. QUA.: The quantitative concept.
APP.: application.
PRO.: problem solving. L: low level. H : high level.
C : the concrete level.
TR. : the the transitional level.
F : the formal operational level.
Act. : the activity on the CAG module
Corr.: correlational reasoning.

Table 3.15 The Average Item Difficulty of Content Areas in the Posttest across the Piagetian Logical Reasoning Levels.

Content Areas		Concrete Level		Transitional Level		Formal Level		Overall	
		I.D.	I.W.	I.D.	I.W.	I.D.	I.W.	I.D.	I.W.
Temp.	Mean	.77	3.50	.60	2.50	.21	3.00	.55	9.00
	S.D.	.24		.32		.21		.18	
Heat	Mean	.82	3.50	.66	6.50	.36	3.83	.62	13.83
	S.D.	.23		.24		.30		.20	
Spec.	Mean	.56	2.00	.58	4.00	.24	2.83	.47	8.83
	S.D.	.39		.27		.24		.22	
Heat Tran.	Mean	.73	6.00	.68	2.00	.18	.33	.70	8.33
	S.D.	.23		.26		.28		.20	
Overall Mean		.74		.63		.28		.58	

I. D. : Average item difficulty.

I.W. : Item weight. If an item was related to two categories of content areas, it accounted for half of the item weight in each category. If the item was related to three categories of the content areas, the item weight accounted for one third in each category respectively.

SECTION FOUR: PROCEDURES

The treatments given were instructional materials, teacher training, pretest, posttest, and interview.

Instructional Materials

Students who were in the experimental group received a copy of the CAG module. See section two.

Students who were in the control group used the NPSC (1988) material. It was the current science curriculum in the Republic of China. See Chapter 1.

Training of the Experimental Teachers

Teachers who were in the experimental group received four hours of training to be familiar with the major ideas of the CAG model and the teaching strategies for the module.

Teacher inservice training was given in a morning one week before the instruction. The objectives of the study were stated at first. The CAG model and its module were explained to the experimental teachers. The main ideas of this model and module were briefly described. Some important student and teacher roles related to the model and module were delimited and provided. The equipment needed in the activities and possible potential problems and solutions were discussed. Procedures for reducing bias were discussed with the teachers.

Five steps related to the CAG model and module were presented as follows:

1. Correlation phase. The first step should provide and teach a correlation of concepts to form a new concept.

2. The first phase of analysis and generalization. Two steps are included to provide concrete activities for students and to move students' descriptive concept level through the comparative concept level to a quantitative concept level by using collection of data, analysis of the data and generalization of data (some concrete examples were given in the teacher training related to the module).

3. The second phase of analysis and generalization. This phase is designed to develop a higher level of learning by analysis and generalization. Two steps were included in this phase; (1) analysis and (2) generalization. In this phase, themes, big ideas, or problems elated to the concepts were included. The main objectives of instruction in this phase are to construct and integrate the knowledge and process skills about the concepts. Detailed anaysis of a theme, a big idea, or problem (such as energy crisis or saving energy) related to the concept is required. A generalization or commonality from the themes, big ideas, or problems are expected to be drawn.

The student's role in the phases of correlation and first cycle of analysis and generalization requires active learning using concrete tasks with little help from the teacher. Students are encouraged to collect their data, mark what they see, describe how it happens, and explain why things occur. Students are also encouraged to draw their own conclusions in small group discussions from their own data.

The teacher's role in the phases of correlation and first cycle of analysis and generalization includes the following: (1) use the teaching strategies in the defined ways; (2) provide some necessary help needed; (3) help students identify answers for the questions in the activities after students have made their own conclusions; (4) encourage small group discussion to develop generalizations based on their own data; and (5) help develop clear pictures for the concepts in descriptive, comparative, and quantitative ways based on the student's statements.

The student's role in the second cycle of analysis and generalization requires constructing knowledge and developing problem skills related to the concepts. Students are encouraged to construct their own knowledge by integrating the related knowledge to the concepts. The inter-relationships between the variables in the content areas are emphasized. Students are encouraged to: (1) develop clear relationships between the concepts and other variables; (2) apply the concepts in some new situations; and (3) use the concepts in solving some related problems.

The teacher's role in the second cycle of analysis and generalization is to provide appropriate and explicit analysis and generalization of the concepts and applications of the concepts for the students. The main purpose of teaching in this phase is to broaden the concepts. A combination of lecture and discussion are encouraged to help students construct their knowledge in an effective way without misconceptions.

Research Design

The design of this study included pretest, instruction, posttest, interview, and follow-up test.

R(1)	O(1)	XE(1)	O(3)	O(5)	O(7)
R(2)	O(2)	XC(2)	O(4)	O(6)	O(8)

R(1) and R(2) represent random assignment of classes to groups and random assignment of the experimental group.

O(1) and O(2) represent the pretest scores for each subject.

Treatments are represented by XE(1) and XC(2) where XE(1) is experimental treatment and XC(2) is the control treatment.

O(3) and O(4) are posttest and observations. O(7) and

O(8) represent the follow-up test scores for each subject. O(5) and O(6) represent interviews.

A pretest was given to the students of both groups two days before the instructional treatment. Both experimental and control groups received two weeks and four days instruction on the topics of temperature, heat, heat transfer, and specific heat. After the instruction, both groups received the posttest. Two weeks after the posttest, the experimental group and control groups both received a follow-up test. Between the posttest and the follow-up test, an interview was administered to 28 selected students from both groups. Each student was interviewed for 40 to 60 minutes.

SECTION FIVE: DATA COLLECTION

Collection of data is discussed under the following subheadings: (1) student's personal background variables including Chinese and mathematics achievement, student's sex, parental occupation, scores on prior knowledge and Piagetian logic thinking; (2) student's science scores on posttest and follow-up test; (3) teacher's emphases in teaching the concepts; and (4) student's reasoning.

Student's Personal Background

The data were collected from the pretest which was administered two days before the instruction.

Student's Scores on Posttest and Follow-up Test

The posttest was administered right after the instruction. The students were notified that they would be given a follow-up test after two weeks. The follow-up test was administered two weeks after the posttest.

Teacher's Emphases on Instruction

After completing the the instruction of the unit, teachers in both experimental and control groups were requested to indicate their emphases in the teaching related to the items of the posttest. The Likert scale was used for relating emphasis to the items on the posttest. Emphasis was ranked from high (1) to low (5) by the teachers.

Student's Reasoning on the Content Areas

Between the time of the posttest and the follow-up test, 28 students were selected from three schools. The selective school was not included. Fourteen were experimental students and 14 were control students(two to three students were slected randomly from each class). Based on the student's answers on the posttest, nine questions were selected to administer for the interview.

The students were asked what their reasoning was on the items. Both correct and incorrect responses were recorded and analyzed. See Appendix E for interview data.

SECTION SIX: DATA ANALYSES

The main purposes of this study were to determine the impact of CAG model and its teaching strategies for eighth grade students and the strong predictors for student science achievement. Student reasoning was also studied. Data analyses used are discussed in four parts: (1) coding data; (2) frequencies and correlation of variables; (3) regression analyses; (4) multivariate analysis of variance; and (5) analyses of student reasoning. The SPSS -X (1988) package was used.

Coding of the Data

Student prior knowledge, student scores on Piagetian logic thinking, students' scores on posttest and follow-up test were obtained as numerical values. Parental occupation was coded dichotomously into categories. If the student parental data applied to the category, the category was coded as 1; if not, it was coded as 0.

The experimental group was coded as 1; the control group was coded as 2.

Males were coded as 1, females as 2.

Frequencies and Correlations

The steps in this part were as follows; (1) frequencies were determined for all variables and (2) correlation matrices were produced for all variables.

Regression Analyses

One stepwise multiple regression analysis was run for the pretest. The personal background variables (including sex, parental occupation, school type), teacher training effect, Chinese, mathematics, prior knowledge, and Piagetian logic thinking were the independent variables and the score of the pretest was the dependent variable.

One stepwise multiple regression analysis was run for the posttest. The variables of sex, Chinese, mathematics, prior knowledge, parental occupations, and Piagetian logic thinking were the independent variables and the score of the posttest was the dependent variable.

One stepwise multiple regression analysis was run for the follow-up test. The pretest, posttest, Chinese, mathematics, prior knowledge, and Piagetian logic thinking were the independent variables and the follow-up score was the dependent variable.

Multivariate Analysis of Covariance

Achievement of Chinese, mathematics, Piagetian logical reasoning, and school types were used as covariates and the posttest and follow-up test were analyzed by analysis of covariance to determine the group effect.

Analysis of student reasoning

The patterns of student reasoning in correct answers and incorrect answers on the selected questions were presented. The implications for curriculum development and teaching strategy were discussed.

CHAPTER IV

THE RESULTS

There are six sections in this chapter. The first section presents frequencies of all selected variables in this study to show the sample characteristics. The second section presents correlation matrices of all variables. The third section presents predictors of students' science achievement. The fourth section presents results of analysis of covariance for testing the group effects. The fifth section presents the analyses of item achievement related to: (1) the sections of the CAG module and teacher emphases; (2) concept domain, applications of the concepts and problem solving; (3) the Piagetian levels. The sixth section presents the analyses of the interview data concerning students' reasoning.

SECTION ONE: THE SAMPLE CHARACTERISTICS.

Descriptive data for types of school, class, sex, and parental occupations across groups are presented. Mean scores of pretest including prior knowledge, mathematical skills, and Piagetian logical thinking across group, class, and sex follow. Finally, data for mean scores of the posttest and follow-up test across class, sex, and group are presented.

Parental Occupations

Tables 4.1 and 4.2 show the distribution of father's and mother's occupations respectively.

Table 4.1 shows that the two most common occupations for fathers were blue collar (workers) and businessmen. Businessmen may be recognized as primarily a middle socio-economic level and blue collar (workers) are considered at a lower socio-economic level in the Republic of China. No other occupation had a level above 15 percent. Table 4.2 shows almost half the mothers worked as housewives or part-time jobs and housewives.

Table 4.1. Frequencies of Father's Occupations.

Category	Experimental Group		Control Group	
	Number of Students	Percent	Number of Students	Percent
F01	29	10.5	26	10.0
F02	112	40.4	94	36.2
F03	89	32.1	103	39.6
F04	15	5.4	10	3.8
F05	2	.7	0	.0
F06	3	1.1	2	.8
F07	15	5.4	16	6.2
F08	5	1.8	3	1.2
F09	1	.4	1	.4
Missing	6	2.2	5	1.9
Total	277	100.0	260	100.1*

F01: Teachers and officers of government.
F02: Business related occupations.
F03: Workers (Blue collar). F04: Farmers.
F05: Soldiers. F06: Medical doctors.
F07: Lawyers, writers, and actors.
F08: Engineers. F09: Unemployed.
* Over 100.0 because some decimal are rounded.

Table 4.2. Frequencies of Mother's Occupations.

Category	Experimental Group		Control Group	
	Number of Students	Percent	Number of Students	Percent
M01	13	4.7	8	3.1
M02	54	19.5	40	15.4
M03	55	19.9	51	19.6
M04	7	2.5	0	.0
M05	1	.4	0	.0
M06	0	.0	0	.0
M07	53	19.1	23	8.8
M08	0	.0	1	.4
M09	78	28.2	132	50.8
Missing	16	5.8	5	1.9
Total	277	100.1*	260	100.0

M01: Teachers and officers of government
M02: Business related occupations
M03: Workers (Blue collar)
M04: Farmers
M05: Soldiers
M06: Medical doctors
M07: Part time job and housewife
M08: Engineers
M09: Housewives
* Over 100.0 because some decimals are rounded.

School Types

Schools involved in this study represented four of the five major types of schools in the Republic of China. There was a selective school, an urban school, a suburban school and a country school. Table 4.3 shows that two classes were selected from the selective school, four classes were selected from the urban school, two classes were selected from the suburban school and four classes were selected from the town and country school.

Table 4.3. Frequencies of Students of the Schools across Groups.

Type	Experimental Group			Control Group.		
	No. of Classes	No. of Student	%	No. of Classes	No. of Student	%
Selective School	1	52	18.77	1	38	14.62
Urban School	2	85	30.69	2	91	35.00
Suburban School	1	39	14.08	1	40	15.38
Town and Country School	2	101	36.46	2	91	35.00
Total	6	277	100.00	6	260	100.00

Sex Distribution

Table 4.4 shows the distribution of the male and female students of the groups. There were a few more boys than girls involved in the study. It also shows a few more students in the experimental group than in the control group.

Table 4.4. Frequencies of Sex across Group.

Category	Experimental Group		Control Group		Total	
	Number of Students	%	Number of Students	%	Number of Students	%
Male	149	53.79	128	49.23	277	51.58
Female	128	46.21	132	50.77	260	48.42
Total	277	100.00	260	100.00	537	100.00

Mean Scores Distributed Among the Classes

Table 4.5 shows the mean scores of the classes on the pretest, Chinese achievement, mathematical achievement, posttest, and follow-up test. The pretest consisted of three parts which were the prior knowledge (Hsum); mathematical skills (Msum); and the Piagetian logical thinking skills (Psum).

The class means of the prior knowledge were distributed from 14.75 to 27.94. The class means of the mathematical skills were distributed from 9.16 to 20.38.

The means of the Piagetian logical thinking skills were distributed from 41.18 to 66.13. The overall average item difficulty of the Piagetian reasoning skills was .68. Item difficulties averaged .99, .81, and .33 at the concrete level, the transitional level, and the formal level, respectively. It indicated that about 99 percent of the grade 8 students had reached or surpassed the concrete level, 80 percent of the students had reached or surpassed the transitional level, and about 30 percent of the students were at the formal level. These data indicate about 20 percent of the students were at the concrete level, 50 percent at the transitional level, and 30 percent at the formal level.

The Chinese achievement scores were distributed in a narrow range at a high level and the mathematical achievement test had a wide range distribution at a relatively low level.

The means of the follow-up test on knowledge were significantly higher than the posttest.

Table 4.5. Mean Scores of the Pretest, Posttest, and Follow-up Test across Classes

Class	Hsum	Msum	Psum	Sum	Chinese	Mathe.	PPsum	PFsum
E1-1	23.06	18.89	58.94	100.89	82.33	68.67	74.67	98.81
C1-1	19.08	15.63	47.50	82.21	59.37	34.08	34.76	53.92
E2-1	15.40	9.16	38.76	63.32	63.08	18.45	40.40	58.53
C2-1	19.81	15.63	49.77	85.23	76.40	41.47	62.09	62.16
E2-2	19.38	17.79	57.06	94.23	67.34	50.96	62.06	76.96
C2-2	27.94	16.96	56.02	100.92	72.90	51.38	72.79	72.04
E3-1	17.14	16.71	54.57	88.41	65.29	54.63	57.26	60.53
C3-1	18.72	15.26	50.30	84.28	64.74	53.83	58.52	63.17
E3-2	22.24	20.38	64.32	106.94	81.62	84.66	80.48	82.88
C3-2	22.24	19.87	66.13	108.24	80.33	87.00	68.02	78.16
E4-1	19.82	18.62	56.18	94.62	86.51	60.82	67.03	75.82
C4-1	14.75	11.00	41.18	66.98	65.70	35.55	37.18	46.03
Total	20.16	16.54	53.97	90.67	72.42	54.78	60.74	70.04
S.D.	5.98	5.01	13.25	20.25	14.63	24.98	19.00	19.94

E1-1, E2-1, E2-2, E3-1, E3-2, and E4-1 represent the classes of the experimental group selected from the four types of schools.
C1-1, C2-1, C2-2, C3-1, C3-2, and C4-1 represent the classes of the control group selected from the four types of schools.
Hsum: the sum of prior knowledge pretest.
Msum: the sum of mathematics pretest.
Psum: the sum of the Piagetian logical thinking pretest.
Sum: the sum of the pretest.
Chinese: the scores of Chinese achievement.
Mathe.: the scores of mathematical achievement.
PPsum: the sum of the post test.
PFsum: the sum of the follow-up test.

Mean Scores Distributed between the Groups

Table 4.6 shows a majority of the test means of the experimental group were higher than those of the control group, except for the mean scores of prior knowledge. The normalized means were distributed between 50 points and 75 points. Average item difficulties of the tests were distributed about from .50 to .75. By comparing the means of the pretest, posttest and follow-up test, it is apparent that: (1) the experimental group made a better gain between the pretest, and posttest than did the control group (r = .22, P=.000, N=537, for total sample favoring the experimental group); and (2) both groups made gains between the posttest and follow-up test. The highest gain between the posttest and follow-up test was made by the experimental group (r = .25, P =.000, N=537, for total sample favoring the experimental group).

Table 4.6. Raw Mean Scores and Normalized Mean Scores of the Pretests, Posttest, and Follow-up Test across Groups.

Gp.	Hsum	Msum	Psum	Sum	Chinese	Mathe.	PPsum	PFsum
Exp.	19.69	17.20	55.63	92.52	74.47	57.97	64.60	76.41
Cntr.	20.65	15.84	52.20	88.69	70.24	51.37	56.64	63.25
Total	20.16	16.54	53.99	90.69	72.42	54.78	60.74	70.04
N-Exp.	50.48	66.15	69.54	63.81	74.47	57.97	59.19	70.11
N-Cnt.	52.97	60.92	65.25	61.16	70.24	51.37	51.96	58.30
N-Tot.	51.66	63.62	67.49	62.54	72.42	54.78	55.72	64.25

Exp.: the experimental group.
Contr.: the control group.
Hsum: the sum of prior knowledge pretest.
Msum: the sum of the mathematics pretest.
Psum: the sum of the Piagetian logical thinking pretest.
Sum: the sum of the pretest.
Chinese: the scores of Chinese achievement.
Mathe.: the scores of mathematical achievement.
PPsum: the sum of the post test.
PFsum: the sum of the follow-up test.
N-Exp. : Normalized means of the experimental group.
N-Cnt. : Normalized means of the control group.
N-Tot : Normalized means of the overall students.

Mean Scores Distributed among Sex and Groups

Table 4.7 shows the means of the tests by sex and group. It shows that male students scored better than female students except on Chinese achievement. Comparisons of the means of the females between groups shows that the experimental females performed better than the control females. The experimental females also scored higher as a group before the treatment. There was difference significant at the .000 level, N=537. See Appendix D for correlation tables.

Table 4.7. Mean Scores of the Pretest, Posttest, and Follow-up Test across Sex.

Gp.	Sex	Hsum	Msum	Psum	Sum	Mathe.	Chinese.	PPsum	PFsum
Exp.	M	20.73	17.36	56.30	94.38	58.96	71.26	67.36	79.84
	F	18.48	17.00	54.86	90.34	56.82	78.21	61.38	74.42
Contr.	M	21.63	16.77	58.66	93.06	52.66	67.51	56.93	65.77
	F	19.71	14.95	49.80	84.46	50.12	72.88	56.35	60.78

Exp.: the experimental group.
Contr.: the control group.
Hsum: the sum of prior knowledge pretest.
Msum: the sum of the mathematics pretest.
Psum: the sum of the Piagetian logical thinking pretest.
Sum: the sum of the pretest.
Chinese: the scores of Chinese achievement.
Mathe.: the scores of mathematical achievement.
PPsum: the sum of the posttest.
PFsum: the sum of the follow-up test.

SECTION TWO: CORRELATIONS BETWEEN VARIABLES

The correlation matrices for all variables are presented in Appendix D. The correlation matrix for some major variables are presented in Table 4.8.

Table 4.8 shows the correlations among group, sex, pretest, Chinese achievement, mathematical achievement, posttest, and follow-up test. Significant differences were found between groups for the posttest(P = .000, N = 537, indicating that the experimental group had higher scores), and the follow-up test (P = .000, N = 537, indicating that the experimental group had higher scores). There was a strong significant correlation between mathematical achievement and science achievement (P =.000, N = 537). The Piagetian logical thinking items were significantly correlated to mathematical achievement (r=.61, P=.000, N= 537), the posttest (science achievement) (r=.59, P=.000, N=537), the follow-up test (science achievement) (r=.51, P=.000, N=537), and Chinese achievement (r= .35, P =.000, N= 537).

Table 4.8. Correlation Matrices of Group, Sex, Prior Knowledge, Mathematical Skills, Piagetian Logical Thinking, Mathematical Achievement, Chinese Achievement, Posttest, and Follow-up Test.

	Sex	Hsum	Msum	Psum	Sum	Mathe.	Chinese	PPsum	PFsum
Group	.05	.08	-.14	-.13	-.09	-.13	-.14	-.21	-.33
P =	.292	.062	.002	.003	.028	.002	.001	.000	.000
(537)									
Sex		-.17	-.11	-.12	-.16	-.05	.20	-.10	-.17
P =		.000	.009	.004	.000	.223	.000	.023	.000
(537)									
Hsum			.48	.43	.70	.41	.32	.57	.49
P =			.000	.000	.000	.000	.000	.000	.000
(537)									
Msum				.57	.76	.62	.36	.55	.51
P =				.000	.000	.000	.000	.000	.000
(537)									
Psum					.92	.61	.35	.59	.51
P =					.000	.000	.000	.000	.000
(537)									
Sum						.67	.41	.69	.60
P =						.000	.000	.000	.000
(537)									
Mathe.							.53	.67	.62
P =							.000	.000	.000
(537)									
Chinese								.52	.57
P =								.000	.000
(537)									
PPsum									.75
P =									.000
(537)									

Group: experimental group was coded as 1, and control group was coded as 2.
Sex: male was coded as 1, and female was coded as 2.
Hsum: the sum of prior knowledge pretest.
Msum: the sum of the mathematics pretest.
Psum: the sum of the Piagetian logical thinking pretest.
Sum: the sum of the pretest.
Chinese: the scores of Chinese achievement.
Mathe.: the scores of mathematical achievement.
PPsum: the sum of the posttest.
PFsum: the sum of the follow-up test.
P: significance of two tail test.

SECTION THREE: IDENTIFYING MAJOR PREDICTORS FOR STUDENT SCIENCE ACHIEVEMENT

In this section some selected variables were analyzed using multiple regression :

1. Student background variables including sex, mathematical achievement, Chinese achievement and parental occupations, and group were selected as the independent variables and the pretest was used as the dependent variable to determine the predictors of the pretest. The results are presented in the Table 4.9.
2. Student background variables including sex, prior knowledge, mathematical skills, Piagetian logical thinking skills, group, mathematical achievement, school types, and Chinese achievement were selected as the independent variables, and the posttest and the follow-up test were selected as the dependent variables, respectively. The results are presented in the Tables 4.10 and 4.11.

The Results of Analyses of Multiple Regression

1. The Predictors for the Pretest

Background variables of students (sex, parental occupations, mathematical achievement, and Chinese achievement) and group were selected as the independent variables and the pretest was selected as dependent variable. The results are presented in the Table 4.9.

Table 4.9 shows mathematical achievement was the strongest predictor of the pretest scores. It accounted for 46 percent of the variance in the explanation of the pretest. Sex came in second and accounted for about 1 percent of the added variance and favored male students. Chinese language, and mother's occupation (teacher or governmental officers) were also significant predictors; each accounted for about 1 percent of th added variance respectively. No other background variables were significant in the regression analysis.

2. The Regression Analyses for Posttest and Follow-up Test

Background variables of students (sex, parental occupations, mathematical achievement, Chinese achievement, prior science knowledge, mathematical skills, and the Piagetian logical reasoning skills), group, and school types were selected as independent variables and the posttest scores, and follow-up scores were selected as dependent variables, respectively.

Table 4.9. Multiple Regression of Student Parental Occupation, Sex, Group, Mathematical Achievement and Chinese Achievement Against the Pretest.

Dependent variable:	Pretest
Multiple R	.70
R square	.49
Adjusted R square	.48
Standard error	14.51

Analysis of variance

	DF	Sum of square	Mean square
Regression	4	106869.71	26717.42
Residual	532	112077.95	210.67
F = 126.82		SigF = .0000	

Variables in the equation

Step	VARIABLE	MULTR	RSQ	ADJRSQ	F(EQN)	SIGT	RSQCH	Slope
1	Mathe.	.67	.46	.45	447.31	.0000	.46	+
2	Sex	.69	.47	.47	237.31	.0000	.01	-
3	Chinese	.69	.48	.48	165.37	.0000	.01	+
4	M01	.70	.49	.48	126.82	.0126	.01	+

Mathe.:the scores of mathematics achievement.
Sex: the sex of the students.
Chinese: the scores of Chinese achievement.
M01:mother's occupations (teachers or officers of government).
Slope: the ' - ' of slope indicates the significance favored male students because of coding.

Table 4.10 shows the predictors of the student background, group, and school types for the posttest. Mathematical achievement was the strongest predictor for the posttest in this analysis. It accounted for 44 percent of explained variance for the posttest. Prior knowledge came in second: it accounted for 11 percent of the added variance. Group was the third variable and accounted for three percent of the added variance (experimental students scored higher than control; the treatment was found to be a significant predictor and favored the experimental group). School type 2 (urban school), the Piagetian reasoning skills, and Chinese language were other significant predictors; each accounted for two percent of the added variance, respectively.

Table 4.11 shows the predictors for the follow-up test. Mathematical achievement was again the strongest predictor; it accounted for 38 percent of the variance. Chinese language was the second highest predictor (eight percent of variance). Language facility appeared to increase in retaining and extending knowledge. Prior knowledge was also a significant predictor and accounted for four percent of the added variance. Group was fourth and accounted for seven percent of the variance favoring the experimental scores. The treatment not only made a difference on the posttest scores but also on the follow-up test.

Table 4.10. Multiple Regression of Student Parental Occupations, Sex, Group, Mathematical Achievement, Chinese Achievement, School Types, Prior Knowledge, Mathematical Skills, and Piagetian Logical Thinking against the Posttest.

Dependent variable:	Posttest
Multiple R	.80
R square	.64
Adjusted R square	.63
Standard error	11.53

Analysis of variance

	DF	Sum of square	Mean square
Regression	6	122898.08	20483.01
Residual	530	70478.94	132.98
F = 154.03,		SigF = .0000	

Variables in the equation

Step	VARIABLE	MULTR	RSQ	ADJRSQ	F(FQN)	SIGT	RSQCH	slope
1	Mathe	.67	.44	.44	426.29	.0000	.44	+
2	Hsum	.74	.55	.55	327.89	.0000	.11	+
3	Group	.76	.58	.58	246.67	.0000	.03	-
4	Schid2	.78	.60	.60	201.28	.0000	.02	+
5	Psum	.79	.62	.62	173.31	.0000	.02	+
6	Chinese	.80	.64	.63	154.03	.0000	.02	+

Mathe.: the scores of mathematics achievement.
Hsum: the sum of prior knowledge pretest.
Group: treatment between the groups. The '- 'of slope indicates the predictor favors the experimental group.
Schid2: the urban school.
Psum: the sum of the Piagetian logical thinking pretest.
Chinese: the scores of Chinese achievement.

Table 4.11. Multiple Regression of Student Parental Occupation, Sex, Group, Mathematical Achievement and Chinese Achievement and the Pretest including Prior Knowledge, Mathematical Skills and Piagetian Logical Thinking against the Follow-up Test.

Dependent variable: Follow-up test

Multiple R	.80
R square	.64
Adjusted R square	.64
Standard error	12.01

Analysis of variance

	DF	Sum of square	Mean square
Regression	6	136856.90	22809.48
Residual	530	76457.56	144.26

F = 123.79 SigF = .0000

Variables in the equation

Step	VARIABLE	MULTR	RSQ	ADJRSQ	F(EQN)	SIGT	RSQCH	slope
1	Mathe	.62	.38	.38	331.78	.0000	.38	+
2	Chinese	.68	.46	.46	231.87	.0000	.08	+
3	Hsum	.72	.52	.51	189.78	.0000	.04	+
4	Group	.77	.59	.58	189.59	.0000	.07	-
5	Schid1	.79	.62	.62	173.76	.0000	.03	+
6	Schid2	.80	.64	.64	158.11	.0000	.02	+

Mathe.: the scores of mathematics achievement.
Chinese: the scores of Chinese achievement.
Hsum: the sum of prior knowledge pretest.
Group: treatment between the groups. The '-' of slope indicates the predictor favors the experimental group.
Schid1: the selective school.
Schid2: the urban school.

SECTION FOUR: TEST OF THE GROUP EFFECTS

ANCOVA and Effect Sizes

Table 4.12 presents the results of ANCOVA for testing the group effects.

ANCOVA was run to test the group effect for the posttest and the follow-up test. According to the results of the regression analyses, mathematics achievement, Chinese achievement, Piagetian logical thinking, and school types were used as covariates to run ANCOVA for the variables of the posttest and the follow-up test. The results were as follows:

Part 1 shows the observed and adjusted means of the posttest and follow-up test.

Part 2 shows the results of ANCOVA(the same covariates used as above) for the posttest and the follow-up test, respectively. A significant difference between groups (F=27.63; df=1, 529; and P=.000) in the posttest was found and favored the experimental group. A significant difference between groups (F=75.53; df=1, 529; and P=.000) in the follow-up test was found and favored the experimental group.

The adjusted mean scores were calculated in part 1 of Table 4.12. The effect sizes were calculated and are in parts 3 and 4 of the Table 4.12.

The effect size using the observed mean scores of the posttest was .41 and favored the experimental group.

The effect size was .73 using the observed scores of the follow-up test and favored the experimental group.

The effect size calculated using the adjusted mean scores of the posttest was .28 and favored the experimental group.

The effect size calculated using the adjusted mean scores of the follow-up test was .52 and favored the experimental group.

The reason for the adjustment was because there were more able students in the treatment group than in the control group. The effect sizes were still positive after adjustment.

Table 4.12 Analysis of Covariance of the Posttest, and the Follow-up Test with Covariates of Mathematical Achievement, Prior Knowledge, Chinese Achievement, School Types, and Piagetian Logical Thinking.

Variates	Covariates
Posttest	Mathematics Achievement
Follow-up test	Prior Knowledge
	Chinese
	Piagetian Reasoning Skills
	School Types:
	School Type 1(the selective school)
	School Type 2(the urban school)

Part 1: Observed and Adjusted Means;

(a) Posttest.

Code	Obs. Mean	Adj. Mean
Experiment Group	64.60	63.33
Control Group	56.63	57.90

(b) Follow-up Test

Code	Obs. Mean	Adj. Mean
Experiment Group	76.41	74.49
Control Group	63.23	65.16

Part 2. Univariate F- Tests with (df= 1, 529).

Variable	Hypoth. MS	Error MS	F	SIG. OF F
Posttest	3647.81	132.01	27.63	.000
Follow up	10745.25	142.25	75.54	.000

Part 3: The Effect Size of Observed Values;

(a) The Posttest

$$\text{Effect Size} = \frac{\text{Mean of Exp.} - \text{Mean of Control}}{\text{Standard Deviation of Control}}$$

$$= \frac{64.60 - 56.63}{19.35} = .41$$

(b) The Follow-up Test

$$\text{Effect Size} = \frac{\text{Mean of Exp.} - \text{Mean of Control}}{\text{Standard Deviation of Control}}$$

$$= \frac{76.41 - 63.23}{18.00} = .73$$

Part 4: Effect Size of Adjusted Values;

(a) The posttest

$$\text{Effect Size} = \frac{\text{Mean of Exp.} - \text{Mean of Control}}{\text{Standard Deviation of Control}}$$

$$= \frac{63.33 - 57.89}{19.35} = .28$$

(b) The follow-up test

$$\text{Effect Size} = \frac{\text{Mean of Exp.} - \text{Mean of Control}}{\text{Standard Deviation of Control}}$$

$$= \frac{74.49 - 65.16}{18.00} = .52$$

SECTION FIVE: ANALYSES OF ITEM ACHIEVEMENT

The Results of Item Achievement Related to the Teacher Emphases and the Content of the CAG Module

Tables 4.13 and 4.14 present analyses of the item difficulties and the teachers' emphases across items of the posttest and the follow-up test. The adjusted item difficulties were calculated by analysis of covariance. Mathematics achievement, Chinese achievement, prior knowledge of science, and Piagetian logical thinking were used as the covariates. ANCOVA results are also presented.

The control group did not perform significantly better than the experimental group on any items of the posttest or of the follow-up test. The items on which the experimental performed better than control group tended to have relatively high teacher emphasis. However, no significant relationship was found between overall teacher emphasis and the posttest or the follow-up test. There were significant differences, favoring the experimental group, on 15 items of the posttest and 30 items of the follow-up test.

Table 4.13 The Comparison of Item Difficulties, and Teacher Emphasis of the Items between Experimental Group and Control Group on the Posttest.

No.	Ob. Item Diff.			Adj. Item Diff.			Sig. F*	Teacher Emp.		
	Exp.	Ctr.	DD	Exp.	Ctr.	DD	ANCOVA	Exp.	Ctr.	DE
Qp1	.64	.58	+.06	.62	.60	+.02	.709	2.00	2.25	+.25
Qp2	.68	.66	+.02	.67	.67	+.00	.988	2.50	2.00	-.50
Qp3	.81	.75	+.06	.81	.75	+.06	.131	2.83	3.00	+.17
Qp4	.56	.51	+.05	.55	.52	+.03	.574	1.83	1.75	-.08
Qp5	.92	.86	+.06	.91	.87	+.05	.095	2.33	2.50	+.17
Qp6	.49	.47	+.02	.48	.48	-.01	.904	3.00	4.00	+1.00
Qp7	.72	.75	-.03	.71	.76	-.05	.213	2.17	2.00	-.17
Qp8	.83	.84	-.01	.83	.84	-.01	.859	2.33	2.25	-.08
Qp9	.81	.77	+.03	.78	.80	-.01	.702	2.00	1.75	-.25
Qp10	.94	.80	+.15	.94	.80	+.14	.000	2.67	4.25	+1.58
Qp11	.70	.59	+.12	.70	.59	+.11	.009	3.00	4.50	+1.50
Qp12	.55	.52	+.03	.54	.52	+.02	.624	2.33	1.75	-.58
Qp13	.84	.72	+.12	.83	.73	+.10	.007	2.33	3.25	+.92
Qp14	.77	.74	+.02	.75	.76	-.01	.824	2.33	2.50	+.17
Qp15	.17	.15	+.02	.17	.15	+.01	.709	2.83	3.00	+.17
Qp16	.47	.46	+.01	.45	.48	-.02	.570	3.50	3.00	-.50
Qp17	.77	.70	+.07	.76	.72	+.04	.278	2.33	2.25	-.08

continue

DD: the difference of item difficulties, ' + ' experimental group higher, ' - ' control group higher.
ANCOVA: Analysis of covariance.
DE: The difference of the teacher emphases, ' + ' experimental group stronger, ' - ' control group stronger.
Ob. item diff. : Observed item difficulty
Adj. item diff. : Adjusted item difficulty
* Significant F's favor the experimental group.

Table 4.13 (continue)

No.	Ob. Item Diff.			Adj. Item Diff.			Sig. F*	Teacher Emp.		
	Exp.	Ctr.	DD	Exp.	Ctr.	DD	ANCOVA	Exp.	Ctr.	DE
Qp18	.56	.49	+.08	.55	.50	+.05	.291	2.00	2.50	+.50
Qp19	.59	.63	-.05	.58	.64	-.06	.130	2.33	2.75	+.42
Qp20	.68	.51	+.17	.67	.52	+.15	.001	1.83	2.25	+.42
Qp21	.83	.76	+.08	.81	.78	+.02	.473	1.83	1.75	-.08
Qp22	.64	.49	+.15	.60	.52	+.07	.027	2.50	2.00	-.50
Qp23	.55	.43	+.11	.52	.46	+.06	.053	2.50	1.50	-1.00
Qp24	.19	.15	+.04	.20	.15	+.05	.049	2.50	2.50	.00
Qp25	.59	.59	+.00	.60	.58	+.02	.653	2.83	2.00	-.83
Qp26	.56	.34	+.22	.53	.37	+.16	.000	2.17	2.25	+.08
Qp27	.26	.15	+.10	.25	.16	+.08	.013	2.67	2.75	+.08
Qp28	.77	.74	+.03	.75	.76	-.01	.888	2.33	1.75	-.58
Qp29	.60	.57	+.02	.58	.59	-.01	.886	2.17	2.75	+.58
Qp30	.82	.72	+.10	.81	.73	+.08	.032	2.00	2.75	+.75
Qp31	.76	.63	+.14	.75	.64	+.11	.001	3.50	3.50	.00
QP32	.84	.79	+.05	.84	.79	+.05	.059	2.67	2.75	+.08
Qp33	.81	.62	+.19	.81	.61	+.20	.000	2.83	3.75	+1.92
Qp34	.22	.10	+.13	.22	.10	+.12	.000	2.83	3.00	+.17
Qp35	.15	.05	+.10	.14	.06	+.08	.001	2.67	2.00	-.67
Qp36	.45	.30	+.14	.42	.33	+.10	.010	2.67	2.25	-.42
Qp37	.92	.81	+.11	.91	.82	+.09	.001	3.33	3.75	+.42
Qp38	.52	.57	-.05	.52	.56	-.04	.370	2.67	2.25	-.42
Qp39	.01	.01	+.00	.01	.01	+.00	.855	3.50	3.25	-.25
Qp40	.60	.57	+.03	.59	.58	+.02	.728	2.17	2.75	+.58

Table 4.14 The Comparison of Item Difficulties between Experimental Group and Control Group on the Follow-up Test.

No.	Ob. Item Diff.			Adj. Item Diff.			Sig. F*	Teacher Emp.		
	Exp.	Ctr.	DD	Exp.	Contr.	DD	ANCOVA	Exp.	Ctr.	DE
Qf1	.78	.67	+.10	.75	.70	+.06	.134	2.00	2.25	+.25
Qf2	.81	.68	+.13	.80	.69	+.11	.002	2.50	2.00	-.50
Qf3	.85	.75	+.09	.84	.76	+.08	.020	2.83	3.00	+.17
Qf4	.72	.57	+.15	.72	.57	+.16	.000	1.83	1.75	-.08
Qf5	.94	.90	+.03	.93	.91	+.01	.603	2.33	2.50	+.17
Qf6	.72	.65	+.08	.71	.66	+.06	.154	3.00	4.00	+1.00
Qf7	.84	.77	+.07	.84	.77	+.07	.043	2.17	2.00	-.17
Qf8	.87	.84	+.03	.87	.84	+.03	.364	2.33	2.25	-.08
Qf9	.90	.77	+.13	.88	.79	+.10	.001	2.00	1.75	-.25
Qf10	.95	.82	+.13	.94	.83	+.12	.000	2.67	4.25	+1.58
Qf11	.87	.74	+.13	.86	.74	+.12	.000	3.00	4.50	+1.50
Qf12	.68	.55	+.13	.68	.55	+.13	.002	2.33	1.75	-.58
Qf13	.86	.72	+.14	.86	.73	+.13	.000	2.33	3.25	+.92
Qf14	.86	.75	+.10	.85	.76	+.09	.010	2.33	2.50	+.17
Qf15	.31	.21	+.10	.32	.21	+.11	.004	2.83	3.00	+.17
Qf16	.80	.54	+.26	.79	.55	+.24	.000	3.50	3.00	-.50
Qf17	.82	.70	+.12	.82	.70	+.12	.001	2.33	2.25	-.08

Continue

DD: the difference of item difficulties, ' + ' experimental group higher, ' - ' control group higher.
ANCOVA: Analysis of covariance.
DE: The difference of the teacher emphases, ' + ' experimental group stronger, ' - ' control group stronger.
Ob. item diff. : Observed item difficulty
Adj. item diff. : Adjusted item difficulty
* Significant F's favor the experimental group.

Table 4.14 (continue)

No. Ob.	Item Diff.			Adj. Item Diff.			Sig. F*	Teacher Emp.		
	Exp.	Ctr.	DD	Exp.	Ctr.	DD	ANCOVA	Exp.	Ctr.	DE
Qf18	.74	.63	+.11	.73	.64	+.10	.019	2.00	2.50	+.50
Qf19	.80	.68	+.12	.80	.68	+.11	.003	2.33	2.75	+.42
Qf20	.66	.50	+.17	.66	.50	+.16	.000	1.83	2.25	+.42
Qf21	.82	.82	+.00	.80	.84	-.04	.205	1.83	1.75	-.08
Qf22	.69	.48	+.21	.66	.51	+.16	.000	2.50	2.00	-.50
Qf23	.68	.49	+.18	.64	.53	+.12	.000	2.50	1.50	-1.00
Qf24	.40	.20	+.19	.39	.20	+.19	.000	2.50	2.50	.00
Qf25	.67	.63	+.04	.67	.63	+.04	.368	2.83	2.00	-.83
Qf26	.63	.49	+.14	.59	.52	+.07	.023	2.17	2.25	+.08
Qf27	.33	.20	+.13	.31	.23	+.08	.021	2.67	2.75	+.08
Qf28	.84	.83	+.01	.81	.85	-.04	.161	2.33	1.75	-.58
Qf29	.76	.65	+.11	.75	.66	+.09	.024	2.17	2.75	+.58
Qf30	.92	.83	+.09	.91	.84	+.07	.009	2.00	2.75	+.75
Qf31	.91	.74	+.16	.89	.76	+.14	.000	3.50	3.50	.00
Qf32	.86	.81	+.04	.85	.82	+.03	.250	2.67	2.75	+.08
Qf33	.83	.75	+.08	.82	.76	+.06	.027	2.83	3.75	+.92
Qf34	.35	.12	+.23	.34	.13	+.21	.000	2.83	3.00	-.17
Qf35	.21	.08	+.13	.19	.10	+.09	.002	2.67	2.00	-.67
Qf36	.61	.35	+.25	.58	.38	+.20	.000	2.67	2.25	-.42
Qf37	.96	.90	+.06	.95	.90	+.05	.018	3.33	3.75	+.42
Qf38	.69	.70	-.01	.69	.71	-.02	.591	2.67	2.25	-.42
Qf39	.22	.01	+.21	.22	.01	+.21	.000	3.50	3.25	-.25
Qf40	.73	.66	+.07	.73	.66	+.07	.092	2.17	2.75	+.58

Table 4.15 presents the adjusted average category difficulties in terms of concept domain (the descriptive concepts, the comparative concepts, and the quantitative concepts), applications of the concepts, and problem solving. The experimental group performed better than the control group on both the posttest and follow-up test in each category (P=.000, N=537).

Table 4.16 presents the adjusted average category difficulties in terms of the Piagetian reasoning levels. The experimental group performed better than the control group on both the posttest and follow-up test (P=.000, N=537, See Appendix D, the Correlation tables).

Table 4.15. The Adjusted Average Categoried Difficulties of the Posttest and the Follow-up test across Groups, Concept Domain, Application of Concepts, and Problem Solving.

Group	DES. Mean	DES. S.D.	CMP. Mean	CMP. S.D.	QUA. Mean	QUA. S.D.	APP. Mean	APP. S.D.	PRO. Mean	PRO. S.D.
Experimental (N=277)										
Posttest	.67	.20	.54	.24	.68	.11	.78	.10	.33	.16
Follow-up	.76	.18	.70	.19	.75	.09	.85	.05	.47	.20
Control (N=266)										
Posttest	.61	.19	.54	.22	.62	.14	.72	.12	.27	.20
Follow-up	.68	.18	.61	.24	.65	.11	.78	.08	.32	.20

DES. : the descriptive concepts. CMP. : the comparative concepts. QUA.: the quantitative concepts. APP.: applications of the concepts. PRO. : problem solving.

Table 4.16. The Adjusted Average Category Difficulties of the Posttest and the Follow-up Test across Groups, and the Piagetian Reasoning Levels.

Group	Test	Concrete Mean	Concrete S.D.	Transitional Mean	Transitional S.D.	Formal Mean	Formal S.D.
Exp.	Posttest	.76	.12	.66	.12	.30	.18
	Follow-up	.85	.08	.75	.08	.46	.21
Contr.	Posttest	.72	.10	.60	.13	.25	.20
	Follow-up	.78	.08	.65	.11	.30	.21

Figure 4.1 presents graphically the adjusted average category difficulties in terms of concept domain, applications of the concepts, and problem solving. It indicates that the experimental group performed better than the control group on the adjusted mean scores of concept domain, applications of the concepts, and problem solving(P=.000, N=537).

Figure 4.2 presents graphically the adjusted average category difficulties in terms of the Piagetian reasoning levels. Data indicate that the experimental group performed better than the control group on the adjusted mean scores of all levels of Piagetian reasoning thinking (P=.000, N=537).

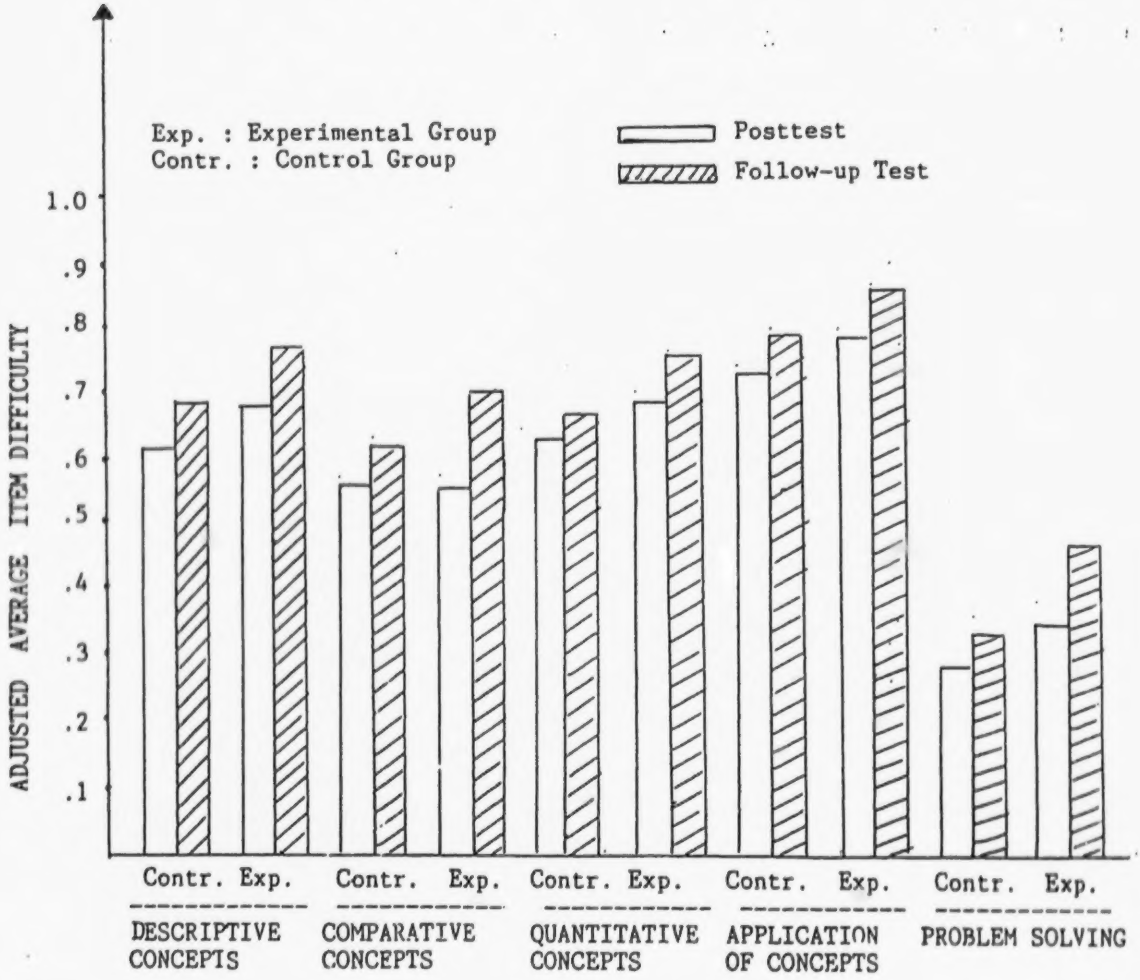


Figure 4.1. The Adjusted Average Category Item Difficulties of Concepts by Domain Applications of the Concepts, and Problem Solving.

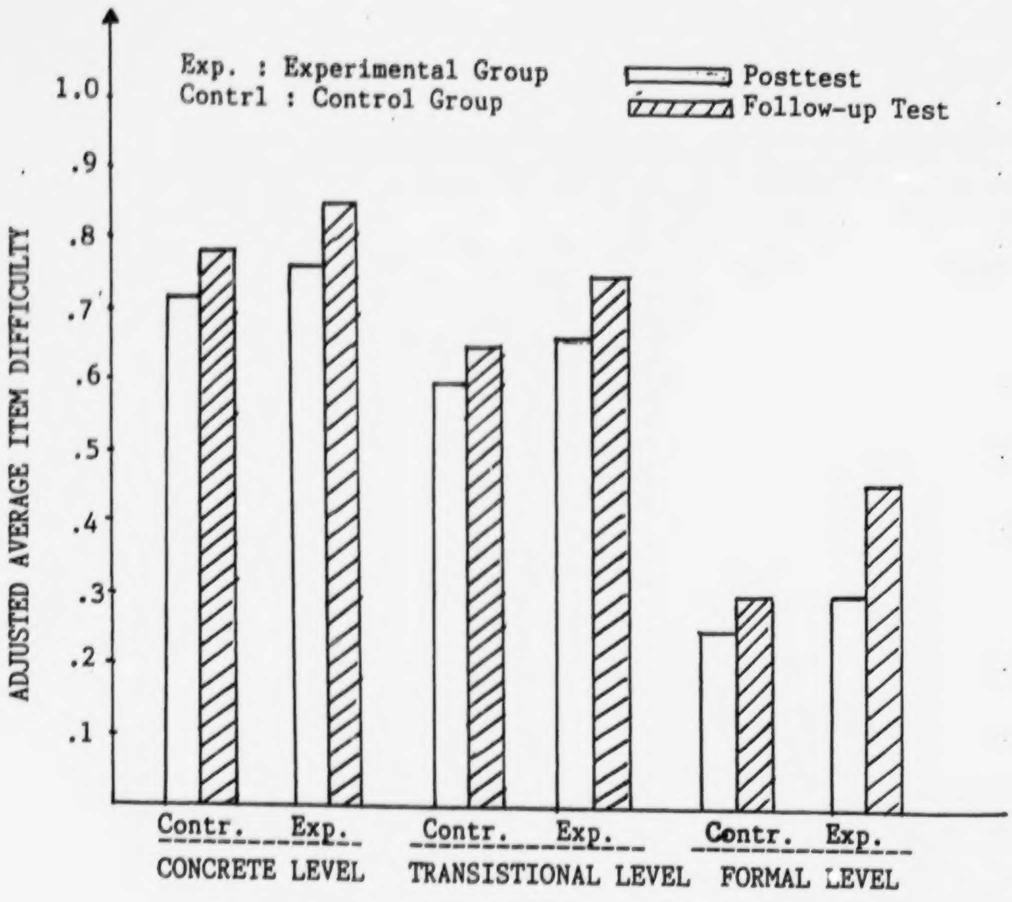


Figure 4.2 The Adjusted Average Category Item Difficulties of the Piagetian Reasoning Levels of the Posttest and Follow-up test.

Table 4.17 presents the items of the posttest on which the experimental group performed significantly better than the control group at the .05 level. Table 4.18 presents the related conceptual schemes of the items. Eleven items were identified consisting of one item at the formal level, four items at transitional level, and six items at the concrete level. In terms of conceptual schemes, heat energy, heat conduction, direction of heat flow, relationships of heat and temperature, quantitative computation of specific heat, heat radiation, controlling of heat transfer, use of thermal equilibrium on problem solving, and correlation of temperature change and some specific natural phenomena were identified. The data indicated that the CAG module had a positive impact on the develpoment of these conceptual schemes and that most improvement was made at the transitional and concrete levels.

Table 4.17 Items of the Posttest on which the Experimental Group Performed Significantly Better than the Control Group at the .05 Level.

	Concept Domain					Process Skills			Piagetian Level			
Que. No.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
10	* (13. 2-3, 13. 1-2)								Corr.	*		
11	* (13. 3-1)								Corr.	*		
13			* (13. 2-3)						Proposi.	*		
20	* (Act. 14)								Corr.		*	
22			* (Act. 14)						Propor.		*	
26			* (13. 4-1)						Corr.		*	
30	* (13. 3-1)								Corr.	*		
31				* (13.1-3)		Formulating Hypothesis	*		Proposi.	*		
33				* (13. 3-2)					Corr.		*	
36					* (Act. 14, 13. 5-1)				Proposi.			*
37		* (Act. 13)				Measuring	*		Corr.	*		

Table 4.18 Items of the Posttest on which the Experimental Group Performed Significantly Better than the Control Group across Its Related Conceptual Schemes.

Question No.	Category of Related Conceptual Scheme
10	Heat is a kind of energy.
11	Scientific concept of heat conduction.
13	To distinguish the concepts between heat and temperature.
20	The condition of heat flow.
22	The relationship between heat change of a substance and its temperature change.
26	A quantitative computation of a specific heat.
30	Definition of heat radiation.
31	Formulating hypothesis related to temperature and natural phenomena.
33	Controlling of heat transfer.
36	Use of principle of thermal equilibrium on problem solving.
37	Correlation of temperature change and change of natural phenomena.

Table 4.19 presents items of the posttest on which both the experimental group and the control group performed well (both groups had high scores in these items) and for which there were no significant differences between groups. The experimental group scores tended to be better than the control group. The related conceptual schemes are stated in Table 4.20. Thirteen items were identified including one item at the formal reasoning level, eight items at the transitional reasoning level, and four items at the concrete level.

Table 4.21 presents items of the posttest on which both the experimental and control groups performed well. The control group scores tended to be better than the experimental group on these items; there were no significant differences between groups. Table 4.22 presents the conceptual schemes related to these items. The control group tended to perform better than the experimental group, but not significantly, on heat convection and its related knowledge.

Table 4.19 Items of the Posttest on which both Groups Scored High with no Significant Difference between Groups across Concept Domain, Skills, and Piagetian Reasoning Levels.

	Concept	Domain				Process Skills			Piagetian	Level		
Ques. No.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
1	* (13. 1-1)								Corr.		*	
2			* (13. 1-4)						Propor.	*		
3				* (Act. 14; 13. 3-2)					Corr.		*	
4			* (13. 2-2)						Corr.		*	
5				* (Act. 13, 14; 13. 1-3)					Corr.	*		
12		* (13. 4-1)							Propor.		*	
17			* (Act. 13, 14)			Interpreting data		*	Proposi.		*	
18				* (Act. 14)					Corr.		*	
21			* (Act. 14)						Proposi.		*	
23					* (Act. 14; 13. 5-1)				Proposi.			*
25		* (13. 4-1)				Interpreting data		*	Proposi.		*	
32				* (13. 3-2)					Corr.	*		
40		* (Act. 15)							Corr.	*		

Table 4.20 Items on which both Groups Scored High with no Significant Difference between Groups across Related Conceptual Schemes.

Question No.	Category of Related Conceptual Scheme
1	A descriptive concept of temperature.
2	A quantitative computation of exchange of temperature scales.
3	An application of controlling of heat transfer.
4	The definition of Cal.
5	Correlation of heat and temperature
12	Specific heat and heat capacity.
17	Heat change with its temperature change.
18	A quantitative calculation of heat change based on its temperature change.
21	Specific heat and temperature change.
23	Heat exchange.
25	Specific heat and temperature.
32	To distinguish between heat conductors and insulators.
40	Specific heat of a substance and its temperature change.

Table 4.21 Items of the Posttest on which both Groups Scored High with no Significant Differences between Groups across Concept Domain, Skills, and Piagetian Levels.

	Concept Domain					Process Skills			Piagetian Level			
Ques No.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
6		* (Act. 13; 13. 1-2)							Corr		*	
7				* (13. 3-1)					Corr.	*		
8				* (13. 3-2)					Corr.	*		
9		* (13. 1-2)							Proposi.		*	
14	* (Act. 15)								Proposi.		*	
16		* (13. 1-4)				Interpre-ting data		*	Propor.			*
19					* (13. 5-1)				Propor.			*
28	* (Act. 14)								Corr.	*		
29	* (13. 3-1)								Corr.	*		
38		* (13. 4-1)							Corr.	*		

Table 4.22 Items of the Posttest on which both Groups Scored High with no Significant Differences between Groups, across Related Conceptual Schemes.

Question No.	Category of Related Conceptual Scheme
6	Kinetic theory for ideal gases
7	Heat convection.
8	The medium of heat conduction
9	Heat exchange and thermal equilibrium
14	Heat exchange and thermal equilibrium.
16	Proportional relationship of the temperature scales.
19	Temperature change related to specific heat and heat change of a substance.
28	Correlation of heat changes, temperature changes, and specific heat.
29	Heat convection.
38	Heat transfer in convection

Table 4.23 presents the difficult items for both groups on the posttest. Table 4.24 presents their related conceptual schemes. Six items were identified, all of them at the formal level. Four items were related to problem solving. In terms of the conceptual schemes, generalized ideas for constructing a thermometer, and concepts related to kinetic theory were found very difficult for both groups in both the posttest and the follow-up test. Thermal equilibrium for multivariables and heat exchange for more than three substances were found to be difficult for the eighth grade students because of the high formal reasoning skills needed. However, the experimental students performed significantly better than those of the control group on these four items. This indicates that the treatment had a positive impact on problem solving items which were at the high formal reasoning level.

Table 4.23 Difficult Items for both Groups on the Posttest across Concept Domain, Skills, and Piagetian Reasoning Levels.

	Concept Domain					Process Skills			Piagetian Level			
Ques. No.	DES.	CMP.	QUA.	APP.	PRO.	Skill Type	L.	H.	Reasoning Type	C.	TR.	F.
15	* (13. 1-1)								Corr.			*
@ 24					* (Act. 14, 15; 13.3-1, 13. 4-1, 13.5-1)	Controlling Vari.		*	Proposi.			*
@ 27					* (13. 4-1, 13. 5-1)				Proposi.			*
@ 34					* (Act. 14, 13. 1-4)				Proposi.			*
@ 35					* (13. 4-1, 13. 5-1)				Corr.			*
39		* (13. 1-2)							Corr.			*

@ : Experimental group performed significantly better than control group at .05 level.

Table 4.24 Difficult Items for both Groups on the Posttest across Related Conceptual Schemes.

Question No.	Category of Related Conceptual Scheme
15	Generalized ideas for constructing a thermometer.
24	Thermal equilibrium for multivariables.
27	Heat exchange for more than three variables.
34	Temperature change related to heat change in Fahrenheit scale.
35	Specific heat including heat exchange.
39	Kinetic theory.

Table 4.25 presents the adjusted class means of the posttest and follow-up test for both the experimental and control groups. Most of the classes performed better on the follow-up test than the posttest.

Figures 4.3 presents the histograms of the adjusted class means of the posttest and follow-up test for both the experimental and control groups (the covariates were mathematics achievement, Chinese, prior knowledge, and Piagetian reasoning skills). Most of the classes performed better on the follow-up test than the posttest, especially for the experimental classes. The data indicated that the classes of both groups improved on the follow-up test and that the experimental classes performed better than the control classes. The differences were significant on ANCOVA analyses at the .000 level (See Table 4.12).

Table 4.25 The Adjusted Class Means of the Posttest and Follow-up Test for both the Experimental Group and Control Group (the Covariates were Mathematics Achievement, Chinese, Prior Knowledge, and Piagetian Reasoning Skills).

Classes	N	Posttest		Follow-up Test	
		Mean	S.D.	Mean	S.D.
E1-1	52	64.77	14.22	90.43	6.52
C1-1	38	44.67	13.89	62.22	18.17
E2-1	38	45.36	9.78	64.86	20.14
C2-1	43	57.13	14.92	55.63	14.83
E2-2	47	65.56	11.11	81.25	13.48
C2-2	48	69.30	11.53	67.75	11.46
E3-1	51	57.38	12.92	60.87	14.24
C3-1	46	58.40	14.06	62.83	13.06
E3-2	50	80.93	12.72	83.56	13.87
C3-2	45	67.56	12.47	77.47	13.16
E4-1	39	59.13	13.00	63.57	14.23
C4-1	40	45.07	11.73	58.30	17.58

E1-1, E2-1, E2-2, E3-1, E3-2, and E4-1 were the classes of the experimental group selected from the four types of schools.
C1-1, C2-1, C2-2, C3-1, C3-2, and C4-1 were the classes of the control group selected from the four tyoes of schools.

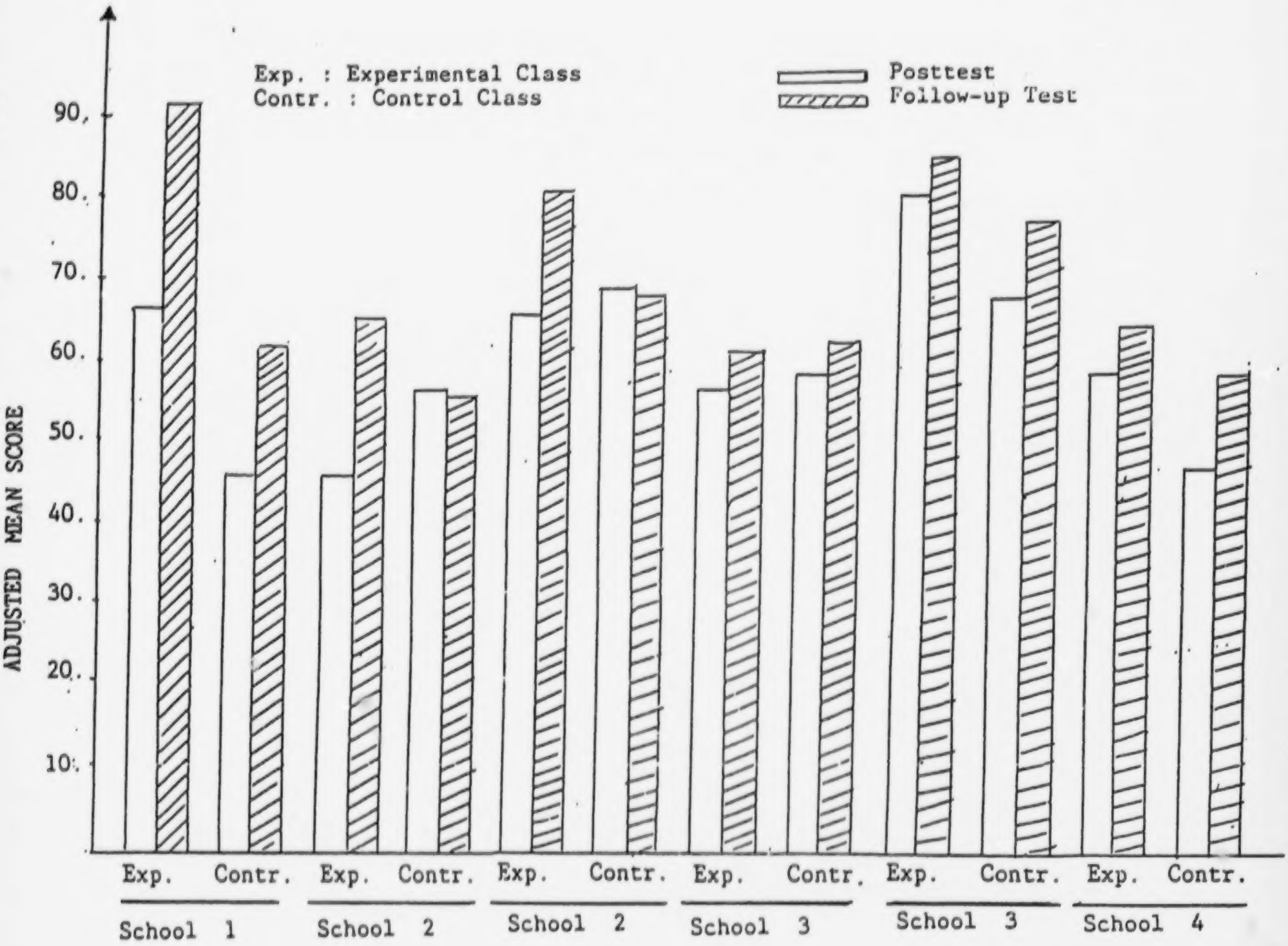


Figure 4.3 The Adjusted Class Means for the Experimental and Control Groups by School on both the Posttest and Follow-up Test.

Summary of the Findings Related to Achievement Using the Module

Based on the analyses the major findings are listed as follows:

1. The total experimental treatment in this study was found to be a strong and significant predictor (P = .000) of science achievement.

2. Significant differences on the posttest (P =.023) and on the follow-up test (P =.000) were found between sexes and favored the male students.

3. The female students in the experimental group performed significantly better (P = .000) than those in the control group on the follow-up test (the treatment accounted for six percent of the added variance of the explanation of the follow-up test).

4. Mathematical achievement was found to be the strongest predictor on the posttest (accounted for variance = .44, P = .000) and on the follow-up test (accounted for variance = .38, P= .000).

5. Chinese achievement and prior knowledge were found to be significant predictors (P= .000) on the posttest and the follow-up test (P =.000).

6. Piagetian logical thinking was found to be highly correlated with the mathematical achievement (r=.61, P=.000), science achievement (r=.59, P=.000), and Chinese

achievement (r=.35, P = .000).

7. No significant correlation was found between teacher emphases and student science achievement; however, there was a positive correlation between the gains of science achievement and experimental teacher emphases.

8. The control group did not perform significantly better (at .05 level) on any item of the posttest or follow-up test than the experimental group.

9. The experimental group performed significantly better than control group on each concept domain, application of the concepts, and problem solving.

10. The experimental group performed significantly better than control group on the posttest and the follow-up test at each level of Piagetian logical reasoning.

SECTION SIX: INTERVIEWING ON STUDENTS' REASONING

Twenty eight-students were selected from three schools (the selective school was not included); 14 students were experimental and 14 were control. Two to three students were selected randomly from each class. Students' responses and selected statements and analyses are included in Appendix E. Most of the results of the analyses of the interviews agreed with test results. Analyses of interviews indicated the following:

1. Concrete experiences were found to be the major background that grade 8 students used to reason about or to solve problems.

2. Kinetic theory was difficult for grade 8 students because of its high formal reasoning level.

3. No student statements were generally in disagreement with test results. However, some misconceptions were identified including the following:

   a. More heat means higher temperature.

   b. A substance with a larger specific heat will increase in temperature faster than a substance with a smaller specific heat (Assuming equal mass and equal amounts of heat).

   c. Heat is composed of invisible particles.

   d. Lack of understanding thermal equilibrium above the concrete level.

4. Students could not use some knowledge to solve problems such as thermal equilibrium except in constructing a thermometer.

CHAPTER V

A SUMMARY OF THE STUDY, DISCUSSIONS OF RESULTS, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

This chapter is presented in three sections: section one describes a summary of the study, section two provides a summary and discussion of the findings, and section three relates the implications, and recommendations for future research.

SECTION ONE: A SUMMARY OF THE STUDY

Introduction

The present study was designed to provide empirical knowledge related to the design of instructional materials and activities to facilitate the learning of concepts and process skills in specific topics of science subject matter. An instructional model (a CAG model which is a learning cycle of Correlation, Analysis, and Generalization) incorporated Piagetian theory and a concept model (Pella, 1975). It was developed and applied to design an instructional module for grade eight students. The module developed for heat and temperature was administered to test its effects by comparing its use with the same topic of the unit in the New Physical Science Curriculum (NPSC).

The major problems of this study were to: (1) develop and analyze an instructional model for a science unit designed for grade eight students; (2) determine its impact on science achievement; and (3) identify what should be done to further improve the materials and instruction.

Population

The population was comprised of eighth grade classes of four types of schools that were among the five major types of schools in Taiwan, Republic of China. The four types of schools from which schools were selected were:

(1) selective schools in cities;
(2) urban schools;
(3) suburban schools; and
(4) town and country schools.

Schools were not selected from the rural areas.

Half of the classes in each school were randomly assigned to the experimental group, and the other half of the classes were assigned randomly to the control group. The six teachers of experimental classes were involved in the experimental group and the six teachers of control classes were involved in the control group. The number of students in the experimental group was 277, and the number of students in the control group was 260.

Instruments

The pretest and the posttest developed by the investigator were the instruments used in this study.

The pretest had three parts: (1) prior knowledge; (2) mathematical knowledge; and (3) Piagetian tasks. Prior knowledge assessed consisted of major concepts of temperature and heat which the students should have learned before grade eight. Mathematical knowledge included number concepts, skills of equation solving, and graphic skills that were required to learn the unit. The Piagetian tasks consisted of proportional reasoning, combinatorial reasoning, and propositional reasoning items that related to the reasoning skills needed to learn the materials presented.

The overall average item difficulty of the prior knowledge test was .51. The average item difficulty of the prior knowledge test at both the concrete level and the transitional levels was .51. The average item difficulties calculated by content areas were .56, .54, .53, and .42 corresponding to temperature, heat, specific heat, and heat transfer respectively.

The pretest contained 12 mathematics skill items. The overall average item difficulty of the mathematics skills was .62. There were item difficulties of .82, .77, and .28 at the concrete level, transitional level, and the formal level respectively.

There were eight Piagetian items in the pretest. The overall average item difficulty of the Piagetian tasks was .68. There were item difficulties of .99, .81, and .33 at the concrete level, the transitional level, and the formal level, respectively.

There were 40 questions contained in the posttest. The items of the posttest and the follow-up test were the same. The items of prior knowledge in the pretest were included in the posttest and the follow-up test. The items developed were based on the content of NPSC and used in a pilot test.

The overall average item difficulty of the posttest was .58 based on the sample of this study. There were item difficulties of .74, .63, and .28 at the concrete level, the transitional level, and the formal level respectively.

Procedures

Students who were in the experimental group received a copy of CAG module. Students who were in the control group used the NPSC (1988) material. NPSC is the current science curriculum in the Republic of China.

Teachers who were in the experimental group received four hours training to be familiar with the major ideas of the CAG model and the teaching strategies for the module.

A pretest was given to the students of both groups two days before the instructional treatment. Both experimental and control groups received about two weeks and four days instruction on the topics of temperature, heat, heat transfer, and specific heat. After the instruction both groups received the posttest. Two weeks after the posttest, the experimental and control groups both received a follow-up test. Between the posttest and the follow-up test an interview was administered to 28 selected students from both groups (14 students from the experimental group, and 14 students from the control group). Each student was interviewed for 40 to 60 minutes.

Data Collection

Data collected included the following: (1) student's personal background variables including Chinese and mathematics achievement, student's sex, parental occupation, student scores on prior knowledge and Piagetian logical thinking; (2) student's science scores on posttest and follow-up test; (3) teacher's emphases in teaching the concepts; and (4) student's reasoning related to the content areas.

The main purposes of this study were to determine the impact of CAG model and its teaching strategies for eighth grade students and the strong predictors for student science achievement. Student reasoning on the concepts related to these topics after instruction was also studied.

SECTION TWO: A SUMMARY OF THE FINDINGS AND CONCLUSIONS

This section consists of seven parts to answer the stated subproblems and its related questions in chapter I (See Chapter I, pages 4 and 5 for subproblems in more detail).

Subproblem 1: Did the treatment group achieve significantly higher than the control group on the achievement posttest and follow-up test (heat and temperature)?

ANCOVA was run to test the group effects for the posttest and the follow-up test. According to the results of the regression analyses mathematics achievement, Chinese achievement, the Piagetian logical thinking, and school types were used as covariates to run analyses for the the posttest and the follow-up test.

The results of ANCOVA for the posttest and the follow-up test respectively showed a significant difference between groups (F=27.63; df=1, 529; and P=.000) on the posttest favoring the experimental group. A significant difference between groups (F=75.53; df=1, 529; and P=.000) on the follow-up test favoring the experimental group.

The effect size of the observed mean scores on the posttest was .41 and favored the experimental group.

The effect size was .73 for the observed scores of the follow-up test and favored the experimental group.

The effect size calculated by the adjusted mean scores for the posttest was .28 and favored the experimental group.

The effect size calculated by the adjusted mean scores for the follow-up test was .52 and favored the experimental group.

It was concluded that the treatment had a significantly positive impact on students' science achievement. The mean treatment effect size reported by Anderson et al. (1983) comparing the National Science Foundation Curricula with traditional curricula was .37. The study of Weinstein et al. (1982) reported a mean effect size was .31 with a standard deviation of .70 when innovative curricula for high school were compared with traditional curricula. The treatment effect sizes measured by the posttest and follow-up test in this study were .28 and .52 respectively. The effect sizes were very similar with Anderson's and Weinstein's findings. However, this study was designed to compare an instructional module with an innovative science curriculum used in the Republic of China.

Subproblem 2: Did the data indicate that the unique features of the module (heat and temperature) contributed to the student's success?

Specific impact of the module can be determined by analyzing item difficulties. The adjusted item difficulties were calculated by analysis of covariance. Mathematics achievement, Chinese achievement, prior knowledge of science, and the Piagetian logical thinking were used as the covariates. The control group did not perform significantly better than the experimental group on any items of the posttest and the follow-up test. Fifteen items of the posttest (including 11 high-scored items and 4 low-scored items) and 30 items (including 24 high-scored items and 6 low-scored items) of the follow-up test were found to have significant differences between groups and favored the experimental group.

Items on which the Treatment Group Scored Significantly Higher

The 11 items with high scores on the posttest on which the experimental group performed significantly better than the control group consisted of one item at the formal level, four items at the transitional level, and six items at the concrete level. In terms of conceptual schemes; heat energy, heat conduction, direction of heat flow, relationships of heat and temperature, quantitative computation of specific heat, heat radiation, controlling of heat transfer, use of thermal equilibrium on problem solving, and correlation of temperature change and some specific natural phenomena were identified as those on which the experimental group performed significantly better than the control group. Results indicated that the CAG module had a positive impact on the development of these conceptual schemes compared to the control curriculum (NPSC).

Items with Good Gains by Both Groups

Thirteen items of the posttest on which both the experimental and control groups performed well with no significant differences between groups were identified (on these items, the experimental group tended to perform better than the control group).

Ten items of the posttest were identified on which both the experimental and control groups performed well. The control group tended to perform better than the experimental group on these items but no significance was found. Heat convection and its related knowledge were in this category. These data indicate that the CAG module related to heat convection should be modified to improve its effectiveness.

Difficult Items for Both Groups

Six difficult items were identified, all of them at the formal level. Four items were related to problem solving. In terms of the conceptual schemes, generalized ideas for constructing a thermometer and concepts related to kinetic theory were found very difficult for both groups on both the posttest and follow-up test. Thermal equilibrium for multi-variables and heat exchange for more than three substances were found to be difficult for the eighth grade students because of the high formal reasoning skills needed. However, the experimental students performed significantly better than those of the control group on these four items. These data indicated that the treatment had a positive impact on the problem solving items which were at the high formal reasoning level, but did not help many students because the majority of the the students were not formal thinkers.

Analysis of Reasoning Levels and Concept Categories

The experimental group performed better than the control group on each type of the concept domain and its applications and problem solving in both the posttest and follow-up test.

The adjusted average category difficulties in terms of the Piagetian reasoning levels showed that the experimental group performed significantly better than the control group in both the posttest and follow-up test at each level.

Characteristics of the Module that Aided effectiveness

There were several reasons why the module was effective. The common characteristics of both the module and NPSC curriculum were:

(1) Both the module and NPSC curriculum were hands-on and student centered materials. The meta-analyses (Shymansky, et al. 1983; Weinstein, et al. 1982; Wise and Okey, 1983) indicated both characteristics tended to be related to effective instruction in science education. Since both programs had these characteristics the effectiveness of both were due, in part, to these characteristics.

(2) Both the module and NPSC tended to use teaching strategies including focusing strategies, manipulative activities and inquiry - discovery strategies. The meta-analyses (Lott et al. 1983; Wise and Okey, 1983) indicated these strategies tended to have positive impacts on science achievement.

The unique characteristics of the module were:

(1) An emphasis on Piagetian logical reasoning.

The module included concern for logical reasoning based on Piagetian stages (Concrete, Transitional, Formal) with an emphasis on concrete and transitional activities and learning requirements. This type of structure has been recommended by others (Albert, 1978; Lawson, 1985; Renner, 1979; Shayer et al. 1979; Staver, 1984) and has been found to be successful. This study indicates that formal learning activities and evaluation items are not apt to be successful with this age group in Taiwan, R. O. C. This finding also is consistent with previous research and provides further support for this consideration in curriculum development and instruction.

The findings from analyses of the difficult items related to content categories of concepts tended to be consistent with the findings of several researchers (Engel Clough, & Driver, 1985; Erickson, 1979; Shayer, 1979; Wiser, 1988). Analyses of this study and the other studies cited indicated: a. difficulties on the concepts of heat and temperature, the applications of thermal equilibrium, and the concepts related to kinetic theory; and b. reasoning skills were apparently required for learning appropriate levels of concepts.

(2) An emphasis on concept learning

The module also included concern for concept learning based on Pella's (1975) model with an emphasis on the sequence of teaching concepts beginning from descriptive concepts through comparative concepts to quantitative concepts. This type of sequence to generalize the concepts has been recommended by Pella et al. (1975). No studies related to the concepts in this study were found that used the Pella's model. Voelker (1968) found that children who were expected to generalize concepts were equally successful as children who were specifically guided in concept acquisition by the teacher. Specific instructional sequences to teach science concepts to elementary school children were conducted by others (Carey, 1968; Helgeson, 1968) and were found to be successful. This study found that the experimental group performed significantly better than the control group on each type of concept domain (P=.000). The finding of this study was consistent with the above studies.

(3) An emphasis on analysis and generalization cycles.

The strategies of effective development of schemata had been proposed and recommended by others (Chi et al., 1981; Rumelhart & Ortony, 1977).

The module included concern for analysis and generalization cycles designed to move student's schemata from low stage to high stage. These learning cycles were developed by the investigator based on Chi's ideas for development of schemata. No studies were found that used this approach for the concepts in this study. The results of this study showed that the experimental group performed significantly better than the control group on each type of concept domain (descriptive, comparative, and quantitative concepts), applications of the concepts, and problem solving. The findings of this study support Rumelhart's and Chi's studies.

Subproblem 3: What students were helped most by the treatment? Did any groups score significantly better than others?

Subproblem 4: Did the treatment aid retention of knowledge? What variables related to retention if it occured?

Student Variables Related to Learning and Retention

Mathematical achievement was the strongest predictor for the posttest. It accounted for 44 percent of variance to explain the posttest. Prior knowledge came in second; it accounted for 11 percent of the added variance. Group was the third variable and accounted for three percent of the added variance (experimental students scored higher than control; the treatment was found to be a significant predictor and favored the experimental group). School type 2 (urban school), the Piagetian reasoning skills, and Chinese language were significant predictors and accounted for two percent of the added variance respectively.

Mathematical achievement was also again the strongest predictor of the follow-up test. It accounted for 38 percent of the variance. Chinese language was the second highest predictor. Language facility appeared to increase in retention and extension knowledge. Prior knowledge was also a significant predictor and accounted for five percent of the added variance. Group was fourth and accounted for seven percent of the variance favoring the experimental scores. The treatment not only made a significant difference on the posttest scores but also on the follow-up test. The treatment increased the student's ability to retain what they had learned.

Fleming and Malone (1983) reported a mean correlation between physical science and mathematics achievement of .48. The mean correlation between language ability and physical science achievement was .55. The correlation between general ability and physical achievement was. 49.

Lee (1987) analyzed the relationships between prior science achievement, instruction, family background, and science achievement for elementary students in the

Republic of China. She found that mathematics and Chinese accounted for 20 to 30 percent of the variance to explain the science achievement.

The pattern of the significant variables (scholastic ability and prior science knowledge) related to science achievement were similar to the findings of the meta-analysis and other studies (Anderson, 1983; Brown, 1983; Galitsis, 1986; Welch, 1986). Mathematics ability, prior science knowledge, language, and Piagetian logical reasoning skills (Lawson, 1985) were identified as the major significantly related variables to science achievement.

Results of this study on the posttest were generally consistent with above studies. In this study the experimental group performed significantly better on the retention (on the follow-up test) of the science achievement; few other studies have explored the retention of learning. Generally, those that emphasize concept and principles show gains also.

Gender and achievement

The experimental females performed significantly better (for adjusted scores, P= .000) than the control group on the follow-up test. The experimental females were also higher as a group before the treatment. Females did not perform significantly better than males in the posttest and follow-up test. This result was consistent with the finding of the meta-analysis (Fleming et al. 1983).

Fleming et al. (1983) indicated that a mean effect size of .32 favoring male students was calculated on science achievement at the middle school level (7-9). Few of studies were specifically related to improving science achievement for females. However, females were found to improve on the scores of the follow-up test in this study. The model and module did a positive impact on the experimental females substantially.

Experimental Classes with High Achievement

The adjusted class means of the Posttest and follow-up test showed that the experimental classes of schools 1 and 3 had good gains and relatively high scores. The experimental classes of schools 1 and 2 made larger improvement on the scores of the follow-up test than the control classes. It indicated that the combination of module, the teachers, and the students were very effective for promoting high achievement.

The experimental classes in schools 1 and 3 performed extremely well. The instruction provided for these students was very effective.

Able and Low Ability Students

Results indicated that the treatment helped both able (high achievement on mathematics and language) and low ability students for their science learning and retention.

Subproblem 5: Did teacher inservice contribute to the student achievement?

The items on which the experimental group performed better than control group tended to have relatively high teacher emphasis. The result indicated that the teacher inservice training did help teacher emphases, but was not significant. No significant relationship was found between overall teacher emphasis and the posttest and the follow-up test.

It was concluded that teacher inservice training tended to have a positive help for the students' achievement, but that more inservice related to specific learning problems was needed. There was substantial variation in teacher effectiveness. In this study experimental classes means in schools 1 and 3 were scored relatively higher than other classes. It indicated that a few of the experimental teachers performed substantially better in their instruction. The teacher's attitude toward instructional materials and the teacher's ability to use appropriately the materials were found to be significant predictors on students' achievement in previous studies (Sweitzer, 1983; Welch, 1985). In this study, a four hour inservice training was conducted. The data of this study were generally consistent with studies of Sweitzer and Welch in spite of the short training time.

A recent study (Roth, 1987) designed materials to achieve gains with no teacher education. This type of material was designed to increase the use of the materials by teachers and also to reduce costs of inservice education. The materials in this study were used with a short inservice period and supports Roth's idea on teacher education. There is a need for these types of materials in most countries. Countries with a central educational system and a national curriculum can implement materials of this type faster and save a substantial amount of money. Changes in the curriculum can also be made much easier than with more traditional materials.

Subproblem 6: Did the evaluation instrument assess learning at more concrete levels appropriately to measure student understanding of content?

Seventy percent of the eighth grade students were at the transitional level or below. Writing of the tests at a more concrete level allowed the students to demonstrate more of what they knew. Students were able to get concrete items right that they would have missed if the items were written at higher levels. Students also did less guessing on more concrete items. Two reasons why it is inappropriate to use a large portion of test items at the formal level in the evaluation instruments are:

(1) Both able and low students would miss these items so no learning related to instruction would be exposed.

(2) Students might misunderstand the meaning of the items rather than misunderstand the concepts which are expected to be measured.

The data of this study showed that the formal items had low gains. Less than 25 percent of the test items on the posttest or follow-up test were at the formal level. The portion of the test items at the formal level in the posttest or the follow-up test was matched with the portion of content at the formal level in the module. It was concluded that the evaluation instruments in this study measured the student understanding of contents for this module appropriately. No related literature was identified for this subproblem.

Subproblem 7: How Specifically Could the CAG Model be Improved through Modification of Materials, Instruction and Inservice Activities?

The CAG module had a positive impact on science achievement. Several findings related to improving of the effectiveness of the module are as follows:

(1) Take into account the prior conceptions of students.

Prior knowledge affecting students' comprehension of science achievement was found by the others (Anderson, et al. 1977; Lee, 1987; Welch, 1985). The correlations among heat energy changes, the quantity and property of the material concerned, and the temperature changes of the material were identified as the most important prior knowledge to affect students' comprehension of this module. The ability to solve equation was identified as the most important mathematical skills for learning the module. Further rewriting of the module should emphasize the prior knowledge of students.

(2) Elaborate more in the transitional level.

About 70 percent of the eighth grade students were identified at the transitional level or below. Results showed that students performed well on the posttest and follow-up test at both the transitional and concrete levels. Instructional materials including concern for Piagetian logical reasoning with an emphasis on concrete and transitional activities and learning requirements have been recommended by several researchers (Albert, 1978;

Lawson, 1985; Renner, 1979; Shayer, et al. 1981; Staver, 1981). A recent study by Rogan (1988) found that more concrete teaching strategies resulted in more effective concept learning on thermal phenomenon. Instruction could be Lowered the formal reasoning level to the transitional level by providing more concrete pictures, examples, concrete tasks, or models to deal with more theoretical conceptual schemes such as:

a. providing more concrete examples for generalized ideas for constructing thermometers;

b. providing more bridging stages for the task of activities to deal with thermal equilibrium for multivariables and for specific heat activities; and

c. providing a concrete model for teaching kinetic theory.

(3) Take into account student misconceptions.

Misconceptions related to heat and temperature have been identified by others (Erickson, 1979; Engel Clough, et al. 1985; Summers, 1980). Results of interviews on students' reasoning of this study were found to be very consistent with the above studies. The major misconceptions were identified as follows:

a. More heat means higher temperature;

b. A substance with a larger specific heat will increase in temperature faster than a substance with a small specific heat (assuming equal mass and equal amount of heat);

c. Heat is composed of invisible particle; and

d. Lack of understanding thermal equilibrium above the concrete level.

Clement (1984) proposed using analogical reasoning to deal with "deep" misconceptions.

Rewriting of the module should consider this approach by:

a. providing opportunities for discussions of alternative ideas in the instruction;

b. providing analogical reasoning; and c. bridging activities to overcome the misconceptions.

(4) Develop carefully the schemata for problem solving and teach strategies for problem solving.

Problem solving was identified as being related to the abilities of analysis and synthesis (NAEP, 1977). The strategies of problem solving have been identified and it is proposed that these strategies can be taught (Chi, et al. 1981; Reif, 1981).

The CAG model concerned the learning cycles with an emphasis on the processes of analysis and generalization to develop schemata. Results of this study showed that the experimental group performed significantly better than the control group on the items of problem solving (P=.000) in both the posttest and follow-up test. It was concluded that the CAG learning cycles had a positive impact on problem solving. More precise strategies for problem solving related to the contents in the module should be emphasized in the rewriting of materials.

(5) Design an evaluation sheet for the module.

Evaluation sheets should be designed for further modification for instructors and students who used the the module to determine the degree of satisfaction related to concept learning, process skill learning, problem solving, and attitude toward science.

(6) Provide a better framework for the module.

Scientific knowledge has been proposed as structured and hierarchical (Champagne, et al. 1981; Erickson, 1979; Reif, 1981). The effective framework of heat and temperature was identified in order as nature of the concept, application of the concept, the relationships among the concepts, problem solving related to the concepts. The sequence of the content in the module was very consistent with above order. However, the module might be more focused on the integration of the concepts among heat, temperature, specific heat and heat transfer.

(7) Rewrite and analyze the contents related to low achievement.

(8) Modify the teacher/student role in instruction and provide inservice related to learning problems of students.

(9) Delete some content not important so as to allow more time to learn important ideas.

(10) Consider more time for important items.

(11) Rewrite part of the module to get more consistency between the model and module (the large part of the module was developed by putting parts of materials together from the available text or curriculum in the U. S. A. See Chapter 3).

(12) Develop a more effective teacher inservice training program.

The teacher's attitude toward the model and module and the mastery of teaching strategies for this model and module maybe important factors for effective teaching. Use of the module by experimental teachers in schools 1 and 3 should provide additional ideas for effective inservice experiences.

SECTION THREE : IMPLICATIONS, AND RECOMMENDATIONS

Introduction

The results of this study showed that the experimental group performed significantly better than the control group on each type of concept domain (descriptive, comparative, and quantitative concepts), applications of the concepts, and problem solving. In terms of Piagetian reasoning levels the experimental group performed significantly better than control group on each level (concrete, transitional, and formal). The findings indicated that the experimental group performed well at the concrete and transitional levels of contents. Based on above results several implications and recommendations are as follows:

Early Development of General Academic Skills for General Achievement

Data showed that both the experimental and control students with better academic abilities (mathematics ability, language ability and reasoning skills) did better on their achievement.

The educational system needs to focus more attention (time, materials, and evaluation) on students at early ages to develop these abilities and skills. Students with lower academic ability levels were not able to gain as much from either the control or experimental treatments. The range of scores between top and bottom students should be decreased.

Use of the CAG MODEL to Revise Current National Curricula

Experimental students outperformed control students on all items where significant differences were determined. This included about 33 percent of the items on the posttest and 75 percent of the items on the follow-up test.

These data indicate that the module and the related instruction was more effective than the control statistically for the total group of students. In addition five of six experimental classes were more effective than the control classes. The sixth comparison classes had essentially no difference between them when scores were adjusted.

Based on these data the national curriculum material for this topic would probably be more effective if modified to fit the CAG model and if the instruction was modified to fit the CAG model.

Since this model was consistently more effective for this topic it probably would be more effective for other units with similar content. The model should be used to revise at least two other similar topics to determine the effectiveness with them. If the model is effective for these two units, then the government should consider substantial revision of materials at the eighth grade level based on the CAG model.

The CAG model was effective for increasing achievement and reasoning skills for grade 8 students. Part of the success was due to the use of more concrete and transitional material and experiences. Students at lower grades need to improve achievement and reasoning skills to be able to achieve at better levels at higher grades. Therefore, student achievement might be further improved by introducing modules based on the CAG model at earlier grades. Three units should be modified at the grade 6 to determine how the unit works for them. If the modules work as expected they would help students to understand and achieve more. In addition, the modules would help students develop more effective reasoning skills.

If the grade 6 intervention is effective, then the government should consider designing curriculum based on the conceptual learning and reasoning skill development ideas developed in this study. An articulated and sequential curriculum of several years duration would likely produce students with better reasoning skills and better understanding of science concepts.

Use of the CAG Model to Improve Learning for Able Students and Females

Experimental students who gained most, compared to control students, were able students and female students.

Students with better preparation were able to easily grasp the ideas in the module and scored very high on the tests; two classes of able students did particularly well. These scores support the need for better science instruction at lower grades to help students develop better reasoning skills and understanding. They also support the use of the CAG model for materials at this grade level to challenge and help our more able students achieve.

Since experimental female students outperformed control females, the module design shows promise for providing an approach to help female students achieve better in science and have more positive attitudes toward science. Use of additional modules will confirm or refute this finding. If the finding is confirmed, then the approach should be applied to more materials to provide more equal learning opportunities for females.

This finding related to females has international significance. In most countries females do not do as well as males in science and have lower interest levels related to science. Since achievement often is related to interests and attitudes, increasing achievement may help improve female attitudes toward science. Use of a sequence of CAG modules in at least one other Eastern country and in one Western country would provide data to determine whether the achievement results might be generalizable.

Problem Solving- A National Problem?

Neither group scored well on problem solving, though the experimental scored better.

Problem solving skills do not develop over a short period of time. Low problem solving scores probably indicate general deficiencies in problem solving skills.

The science curriculum needs to be designed to teach reasoning skills required for problem solving (and other categories of thinking such as critical thinking, creative thinking and decision-making) in a sequential, hierarchical pattern. These skills should be initially taught in a concrete way, then transitional, and later formal.

The unit in this study should be modified to be more effective in helping problem solving, but a simple unit taught over a four to five week period of time will not make fundamental changes in the problem solving abilities of a majority of the students.

This finding related to problem solving is another one with international significance. Nearly all countries that have a history of science education research have found similar results- low problem solving scores. A number of models exist for revising a curriculum to improve problem solving. Taiwan (R. O. C.) could provide leadership in developing a curriculum that would improve problem solving skills in a significant way.

Use of Effective Teaching Styles for Improving Instruction and Learning Related to Science

The performance of several teachers was substantially better than others (when comparing adjusted scores). These teachers made more effective use of the materials with the students.

The instruction of these teachers should be analyzed to determine if there are common practices they use. If there are, then these practices should be incorporated into inservice activities to determine if they would make other teachers more effective. If the results of such an experiment are positive, then similar approaches should be tested in teaching other CAG modules to determine if they are equally effective. A plan of analyzing high teacher performance for refining instructional procedures used with the CAG modules should provide an effective blend of good instructional materials and good instructional procedures that work with specific student groups.

Reducing Student Misconceptions Related to Science

All students come to school with misconceptions about science concepts. This study adds to the developing literature of research related to misconceptions in physics.

While more research needs to be done to determine more misconceptions, curricula should be developed that correct misconceptions. This study provides a model for improving learning by testing a module, determining misconceptions, revising the module, and then testing again.

The module used in this study should be revised based on misconceptions identified, tested with students and analyzed to determine if the revised module is more effective.

In addition, modules used earlier in the curriculum that relate to this topic should be analyzed to determine how they present the concepts; some of these units or modules should probably also be revised.

The development and testing of additional modules (See above) should follow a similar pattern to improve both the modules being tested and the curriculum of earlier grades.

APPENDIX A

THE PRETEST -- English translation from Chinese.

Note: In some cases meanings are slightly different due to difference in language.

School:_________, Class:__________, ID #:________,

Sex:_______, Name:__________.

Father's occupation: Circle one of the following occupations: 1. Teachers or officers of government, 2. Business related occupation, 3. Worker, 4. Farmer. 5. Soldiers, 6. Medical doctors, 7. Lawyers, writers, and actors, 8. Engineers, and 9. Unemployed.

Mother's occupation: Circle one of the following occupations: 1. Teachers or officers of government, 2. Business related occupation, 3. Worker, 4. Farmer. 5. Soldiers, 6. Medical doctors, 7. Part time job and housewife, 8. Engineers, and 9. Housewife.

Part A: Prior Knowledge (including correct answers)

( ) 1. Which is a correct statement related to definition of temperature ?

(1) quantity of heat a material holds.
(2) the degree of hotness to a material.
(3) both of statements (1) and (2) above.
(4) none of above.

Correct Answer: 2

( ) 2. How many degrees Fahrenheit is equivalent to 30 degrees Celsius?

(1) 60
(2) 69
(3) 72
(4) 86

Correct Answer: 4

( ) 3. The design of a bath heating tank always has the inlet in the bottom of the tank and the outlet in the upper part of the tank. This is considered an application of heat transfer in water by the way of

(1) conduction
(2) convection
(3) radiation
(4) both conduction and radiation

Correct Answer: 2

( ) 4. Cal is considered an unit of heat quantity. One Cal is defined as:

(1) The quantity of heat absorbed by one gram of any substance in raising it one degree Celsius.
(2) The quantity of heat absorbed by one gram of any substance and raising it one degree Fahrenheit.
(3) The quantity of heat absorbed by one gram of water and in raising it one degree Celsius.
(4) The quantity of heat absorbed by one gram of water in raising it one degree Fahrenheit.

Correct Answer: 3

( ) 5. A rise in temperature of a material indicates that

(1) it absorbs some heat.
(2) it gives up some heat.
(3) no heat is absorbed or rejected.

Correct Answer: 1

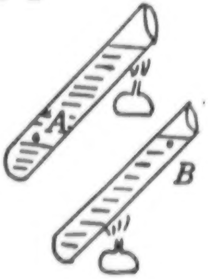
( ) 6. There are three assumptions related to increasing of temperature of gases; (A) expansion of its volume. (B) increase of its molecular speed. (C) increase of its molecular average kinetic energy. Which of the following is the best choice?

(1) (A).
(2) (A) and (B).
(3) (A), (B), and (C).
(4) (A) and (C).

Correct Answer: 3

( ) 7. Consider that two tubes which contain the same mass of water were heated at the ends, as indicated in the following figure for a very short time. Which of the following statements is true about the temperatures at points A and B.

(1) The temperatures at both point A and point B were the same.
(2) The temperature at point A was greater than that at point B.
(3) The temperature at point A was less than that at point B.
(4) Can not be determined in this situation.



Correct Answer: 3

( ) 8. The conduction of heat takes place most easily through

(1) metal
(2) liquid
(3) gases
(4) space

Correct Answer: 1

( ) 9. If you added equal amounts of water at 20 and 40 degrees Celsius, the final temperature of the mixture is

(1) 20 degrees Celsius
(2) 30 degrees Celsius
(3) 40 degrees Celsius
(4) 60 degrees Celsius

Correct Answer: 2

( ) 10. Heat can be converted from what kind of energy?

(1) Mechanical energy.
(2) Electric energy.
(3) Solar energy.
(4) All of above can be converted into heat.

Correct Answer: 4

( ) 11. Heat is conducted through an object if the molecules

(1) increase in size.
(2) decrease in size.
(3) slow down in speed.
(4) collide with each other.

Correct Answer: 4

( ) 12. The specific heat of silver, aluminum, and copper are .056, .221, and .093 cal/g°C, respectively. Consider a 1 gram amount of each. If they are heated enough to raise one degree Celsius, which metal absorbs the largest amount of heat?

(1) silver
(2) aluminum
(3) copper

Correct Answer: 2

( ) 13. If 200 grams of water at 100 degrees Celsius is poured half of its mass, which of the following statements is correct?
(1) The temperature is still 100 degrees Celsius but some of its heat is lost.
(2) The temperature drops and some of its heat is lost.
(3) The temperature drops and no heat is lost.
(4) The temperature increases and some of its heat lost.

Correct Answer: 1

( ) 14. A copper ball weighing 20 grams and having a specific heat of .093 cal/g°C is heated to 300 degrees Celsius then put it into 1000 grams of water initially at 20 degrees Celsius. What is the final temperature of the copper ball in the warm water?

(1) still at 300 degrees Celsius.
(2) lower than 300 degrees Celsius, but higher than 20 degrees Celsius.
(3) lower than 20 degrees Celsius.
(4) 20 degrees Celsius.

Correct Answer: 2

15. How much heat, in calories, is required to heat 200 grams of water from 15 degrees to 85 degrees Celsius?

Solution:

Data: M_w = mass of water = 200 grams
T_i = 15 °C
T_f = 85 °C
Q = Calories of heat = ?

Basic Equation:

$$Q = M_w \ (T_f - T_i)$$

Substitution:

$$Q = 200 \times (85 - 15) = 200 \times 70 \text{ cal} = 14000 \text{ cal}$$

Correct Answer: 14000 cal

16. Write the relationship among H (heat absorbed by a substance), M (mass of the substance), T (the temperature gained of the substance), and S (the specific heat of the substance).

Correct Answer: H = M S T

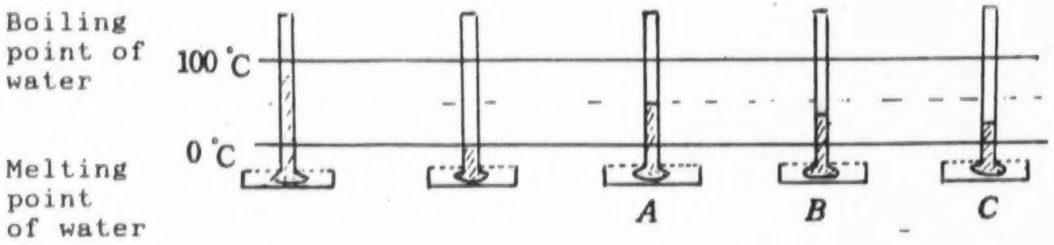
17. Heat transfer from or to a moving liquid or gas in which the motion is caused by the variations in density due to temperature change is called ______.

Correct Answer: Convection

18. Heat transfer from one place to another place not requiring a physical medium is called __________.

Correct Answer: Radiation

19. The diagrams present the measured temperatures. Identify the correct diagram for the following items (1), (2), and (3) below.


Boiling point of water
100 °C
0 °C
Melting point of water
A
B
C

(1) Body temperature: ___________

(2) 50 degrees in Celsius: ___________

(3) Room temperature: ___________

Correct Answer: (1): B
(2): A
(3): C

Part 2: Mathematical Skills

Complete the following blanks.

1. 2, 4, 6, 8, ___, 12, 14, ...

Correct Answer: 10

2. 2, 4, 8, 16, ___, 16, 8, 4, 2.

Correct Answer: 32

3. 1, .5, .25, _____, .0625, .03125,.......

Correct Answer: .125

4. 1, 3, 9, 27, ___, ___, 9, 3, 1.

Correct Answer: 81, 27

5. Consider a*b*c = x*y*z.
If a=4, b=2, c=3, x=2, and z=2 then
y equals to ________.

Correct Answer: 6

6. Consider y=a*b*c.
If a=2, b=5, and c=7, then y = _______.

Correct Answer: 70

7. Consider Y=a*b*c.
If y=60, a=2, and c=10, then c =________.

Correct Answer: 3

8. Consider y = a + b*x.
If a=32, b=9/5, and x=40 then y = ____.

Correct Answer: 104

9. ( ) Consider A is proportional to B and C, B is proportional to 1/C then A can be

(1) k(B+C)
(2) K B/C
(3) kBC
(4) kC/B
Where K is a proportional constant.

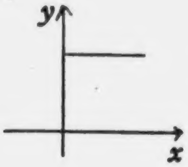
Correct Answer: 3

10. Consider 40 (x-30) = 50 (50 -x), then x = _______.

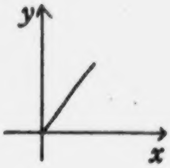
Correct Answer: 370/9

11. ( ) Identify the diagram that indicates the slowest increasing of y with increasing of x.

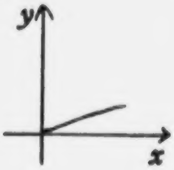
(1)



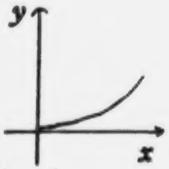
(2)



(3)



(4)



Correct Answer: 1

12. ( ) Identify the table that indicates the fastest increasing of y with increasing of x.

(1)

y	1,	2,	3,	4
x	91,	92,	93,	94

(2)

y	2,	4,	6,	8
x	91,	92,	93,	94

(3)

y	1,	7,	13,	20
x	10,	13,	16,	19

(4)

y	1,	4,	7,	10
x	10,	11,	12,	13

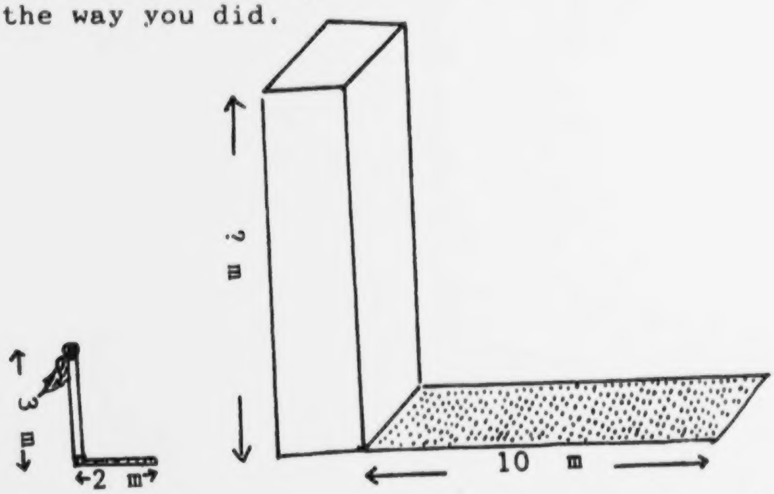
Correct Answer: 4

Part 3: Piagetian Logical Thinking

Task 1: Proportional Reasoning

1. If one pencil costs 2 dollars then 5 pencils cost ____ dollars.

2. The lengths of the shadow of a post and a building measured at the same time of day.
The building shadow's length is 10 meters.
The post shadow's length is 2 meters.
The height of the post is 3 meters.
How many meters tall is the building?
Show your calculations. Write a paragraph to explain why you computed the height of the building the way you did.



Task 2: Propositional Reasoning

4. Consider A=10, B=5, and C=7
What is the order from large to small.
____, ____, _____.

5. All the police cars are black. Here is a black car, should it be a police car?
Is your answer yes or no?
Explain your answer.

6. A student investigated a ball which was moving on a horizontal plane. He found that the ball was moving slower and slower and stopped at last. The student concluded that several factors might cause the ball to be stopped so he decided to study it further. According to the science text he found it might be caused by air resistance, some external forces from the environment, or the friction between the ball and the surface.

Another experiment was done in a laboratory. The student found that a ball was moving in a horizontal plane and never slowed down for a long time.

If you were the student what factors would you conclude (air resistance, friction, and forces from the environment) were related to the moving ball?

Task 3: Combinatorial Reasoning

7. John has two shirts : one is white and the other is brown. He also has three pairs of pants which are black, green, and blue. How many possible combinations does he have for dressing? List all of them. One possible pair listed.

Shirt : pant
white : black

_____:_____ _____;_____ _____:_____

_____:_____ _____:_____ _____:_____

_____:_____ _____:_____ _____:_____

8. A string is tied around a piece of metal and placed on a table. The hook of the string scale is lifted and the metal is held above the table. The scale shows a reading of the weight of the metal in the air. The metal is kept attached to the scale and placed in a container of liquid. The metal is lowered into the water so it is completely covered. The metal does not touch the side or bottom of the container. The scale now shows a reading of weight of the metal in the liquid.

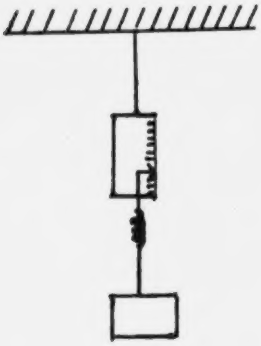
Suppose there are 100 grams of two metal substances (gold and copper) with volumes of 5.18 centimeter cubic and 11.23 centimeter cubic, respectively. There are two kinds of liquid (water and alcohol) with densities of 1.00 gram per centimeter cubic and .79 gram per centimeter cubic, respectively. Evidence listed below was collected.

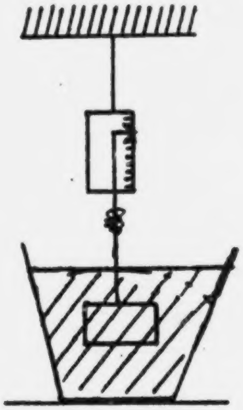
(A) The gold apparently lost 5.18 grams of its weight when it was measured by placing it in the container of water and 4.1 grams when measured in alcohol.

(B) The copper apparently lost 11.23 gram of its weight in the water container and lost 8.87 grams in the alcohol container.

(1) What are the variables related to the apparent loss of weight in measuring the metal in the containers of liquids? Explain your answer.

(2) What are the relationships between the variables and the apparent loss of weight of the metal? Explain your answer.





- End of Test -

APPENDIX B.

THE POSTTEST (including correct answers) -- English translation from Chinese.

Note: In some cases meanings are slightly different due to difference in language.

School:__________, Class:___________, ID #:_________,

Sex:_______, Name:___________.

( ) 1. Which is a correct statement related to definition of temperature ?

(1) quantity of heat a material holds.
(2) the degree of hotness to a material.
(3) both of statements (1) and (2) above.
(4) none of above.

Correct Answer: 2

( ) 2. How many degrees Fahrenheit is equivalent to 30 degrees Celsius?

(1) 60
(2) 69
(3) 72
(4) 86

Correct Answer: 4

( ) 3. The design of a bath heating tank always has the inlet in the bottom of the tank and the outlet in the upper part of the tank. This is considered an application of heat transfer in water by the way of

(1) conduction
(2) convection
(3) radiation
(4) both conduction and radiation

Correct Answer: 2

( ) 4. Cal is considered an unit of heat quantity. One Cal is defined as:

(1) The quantity of heat absorbed by one gram of any substance in raising it one degree Celsius.
(2) The quantity of heat absorbed by one gram of any substance and raising it one degree Fahrenheit.
(3) The quantity of heat absorbed by one gram of water in raising it one degree Celsius.
(4) The quantity of heat absorbed by one gram of water in raising it one degree Fahrenheit.

Correct Answer: 3

( ) 5. A rise in temperature of a material indicates that

(1) it absorbs some heat.
(2) it gives up some heat.
(3) no heat is absorbed or rejected.

Correct Answer: 1

( ) 6. There are three assumptions related to increasing of temperature of gases; (A) expansion of its volume. (B) increase of its molecular speed. (C) increase of its molecular average kinetic energy. Which of the following is the best choice?

(1) (A).
(2) (A) and (B).
(3) (A), (B), and (C).
(4) (A) and (C).

Correct Answer: 3

( ) 7. Consider that two tubes which contain the same mass of water were heated at the ends, as indicated in the following figure for a very short time. Which of the following statements is true about the temperatures at points A and B.

(1) The temperatures at both point A and point B were the same.
(2) The temperature at point A was greater than that at point B.
(3) The temperature at point A was less than that at point B.
(4) Can not be determined in this situation.

Correct Answer: 3

( ) 8. The conduction of heat takes place most easily through

(1) metal
(2) liquid
(3) gases
(4) space

Correct Answer: 1

( ) 9. If you added equal amounts of water at 20 and 40 degrees Celsius, the final temperature of the mixture is

(1) 20 degrees Celsius
(2) 30 degrees Celsius
(3) 40 degrees Celsius
(4) 60 degrees Celsius

Correct Answer: 2

( ) 10. Heat can be converted from what kind of energy?

(1) Mechanical energy.
(2) Electric energy.
(3) Solar energy.
(4) All of above can be converted into heat.

Correct Answer: 4

( ) 11. Heat is conducted through an object if the molecules

(1) increase in size.
(2) decrease in size.
(3) slow down in speed.
(4) collide with each other.

Correct Answer: 4

( ) 12. The specific heat of silver, aluminum, and copper are .056, .221, and .093 cal/g°C, respectively. Consider a 1 gram amount of each. If they are heated enough to rise one degree Celsius, which metal absorbs the largest amount of heat?

(1) silver
(2) aluminum
(3) copper

Correct Answer: 2

( ) 13. If 200 grams of water at 100 degrees Celsius is poured half of its mass, which of the following statement is correct?

(1) The temperature is still 100 degrees Celsius but some of its heat is lost.
(2) The temperature drops and some of heat is lost.
(3) The temperature drops and no heat is lost.
(4) The temperature increases and some of heat is lost.

Correct Answer: 1

( ) 14. A copper ball weighing 20 grams and having a specific heat of .093 cal/g°C is heated to 300 degrees Celsius then put it into 1000 grams of water initially at 20 degrees Celsius. What is the final temperature of the copper ball in the warm water?

(1) still at 300 degrees Celsius.
(2) lower than 300 degrees Celsius, but higher than 20 degrees Celsius.
(3) lower than 20 degrees Celsius.
(4) 20 degrees.

Correct Answer: 2

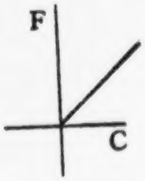
( ) 15. Which of the following is the most precise statement related to the thermometer?

(1) Only the property of expansion can be applied to design a thermometer.
(2) Any property in any substance can be applied to design a thermometer if that property's relationship to temperature is clear.
(3) Only a property of a substance which is linearly related to the temperature change can be applied to design a thermometer.
(4) In general, a thermometer can be used to measure both the very low and very high temperatures.

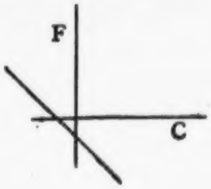
Correct Answer: 2

( ) 16. Which is the correct plot of the relationship between Fahrenheit and Celsius scale?

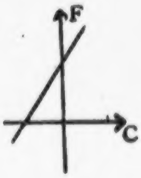
(1)



(2)



(3)



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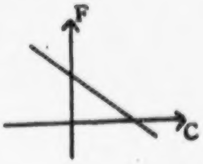
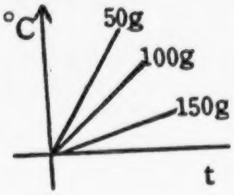


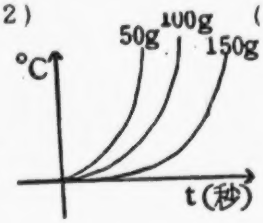
Correct Answer: 3

( ) 17. If three cups of water with mass of 50 grams, 100 grams, and 150 grams, respectively are heated under the same condition. Which diagram contains the correct data?

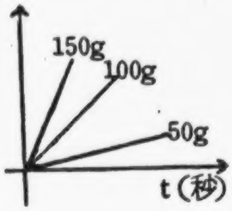
(1)



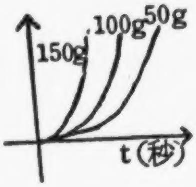
(2)



(3)



(4)



Correct Answer: 1

( ) 18. Both white and black cups of water are at 80 degrees Celsius initially and then put in a room at 20 degrees. Will the water in the black cup cool faster than the water in the white cup?

(1) yes.
(2) cooling will be at the same rate.
(3) no.
(4) can not be determined.

Correct Answer: 1

( ) 19. The same amount of heat is absorbed by substance A and B which have the same mass. If the specific heat of A is twice B, how much the ratio of temperature differences results between substances A to B?

(1) 2 times
(2) 1/2
(3) the same
(4) can not be calculated.

Correct Answer: 2

( ) 20. Which is a correct statement related to the concept of heat?

(1) Heat is composed of a lot of invisible particles which flow from points of high temperature to low temperature.
(2) Heat is a kind of energy and it flows from high temperature to low temperature.
(3) Heat is a kind of energy and it flows from matter with large heat to small.
(4) heat flows from matter with large specific heat to small one.

Correct Answer: 2

Calculate the values and explain your answers in the following questions.

21. How much heat, in calories, is required to heat 200 grams of water from 15 degree to 85 degree Celsius?

Solution:

Data: M_w = mass of water = 200 grams
$T_i = 15\ ^\circ C$
$T_f = 85\ ^\circ C$
Q = Calories of heat = ?

Basic Equation:

$$Q = M_w\ (T_f - T_i)$$

Substitution:

$$Q = 200 \times (85 - 15) = 200 \times 70 \text{ cal} = 14000 \text{ cal}$$

Correct Answer: 14000 cal

22. A cup of water at 14 degrees Celsius is heated under a constant rate for 2 minutes and its temperature rises to 18 degrees; heated for 10 minutes its temperature rises to 34 degrees. What is the temperature of the water when it is heated for 5 minutes?

Solution:

Data: To = 14 °C, to = 0 min.
Tf1 = 18 °C, t1 = 2 min.
Tf2 = 34 °C, t2 = 10 min.
Tf3 = ? t3 = 5 min.

Basic Equation:

$$\frac{\mathrm{Tfi} - \mathrm{To}}{\mathrm{Tfj} - \mathrm{To}} = \frac{\mathrm{ti} - \mathrm{to}}{\mathrm{tj} - \mathrm{to}}$$

Substitution:

$$\frac{18 - 14}{\mathrm{Tf3} - 14} = \frac{2 - 0}{5 - 0}$$

$$\frac{4}{\mathrm{Tf3} - 14} = \frac{2}{5}$$

$$2\,(\mathrm{Tf3} - 14) = 20$$

$$2\,\mathrm{Tf3} = 48$$

$$\mathrm{Tf3} = 24$$

Correct Answer: 24 °C

23. What is the result of adding 400 grams of water at 20 degrees Celsius into 200 grams of water at 80 degrees Celsius?

(1) Calculate the final temperature of the mixture.

(2) Calculate the heat exchange in this mixture.

Solution for (1):

Data:
M1 = 400 grams
T1 = 20 °C
M2 = 200 grams
T2 = 80 °C
MT = M1 + M2 = 600 grams
Tf = ?

Basic Equation:

$$QT = Q1 + Q2$$
$$MT \times Tf = M1 \times T1 + M2 \times T2$$

Substition:

$$600\ Tf = 400 \times 20 + 200 \times 80$$
$$Tf = 40\ °C$$

Correct Answer: 40 °C

Solution for (2):

Data:
M1 = 400 grams
T1 = 20 °C
Tf = 40 °C

Basic Equation:

$$Q = M \times (Tf - Ti)$$

Substitution

$$Q = 400 \times (40 - 20) = 8000 \text{ cal}$$

Correct Answer: 8000 cal

24. Put three metal balls (gold, copper, and aluminum) each 20 grams and at 20 degrees Celsius respectively into a cup of water. The temperature of the water is kept at 100 degrees Celsius. The specific heat of gold, copper, and aluminum are .031, .092, and .211 cal/g °C, respectively.

What temperatures will the metal balls be in the boiling water?

Gold ball. ______________________

Copper ball. ______________________

Aluminum ball. ______________________

Correct Answer: The three metal balls were at the same temperature of 100 degrees Celsius.

Consider the metal balls are picked up from the boiling water and put into seperate cups of water (each cup contains 20 grams of water and is at 20 degrees Celsius). What are the final temperatures of the metal balls in the cup of water that was at 20 degrees Celsius initially?

Gold ball. ______________________

Copper ball. ______________________

Aluminum ball. ______________________

Solution for gold ball:

Data:
$M1 = 20$ grams
$c1 = .031$ cal/g °C
$T1i = 100$ °C
$Mw = 20$ grams
$Twi = 20$ °C
$Tf = ?$

Basic Equation:

$$Tf \times (c1 \times M1 + Mw) = c1 \times M1 \times T1i + Mw \times Twi$$

Substitution:

$$Tf (.031 \times 20 + 20) = .031 \times 20 \times 100 + 20 \times 20$$
$$20.62\ Tf = 462$$
$$Tf = 22.4\ ^\circ C$$

Correct Answer: 22.4 °C

Solution for copper ball:

Data:

$M2 = 20$ grams
$c2 = .092$ cal/g °C
$T2i = 100$ °C
$Mw = 20$ grams
$Twi = 20$ °C
$Tf = ?$

Basic Equation:

$$Tf \times (c2 \times M2 + Mw) = c2 \times M2 \times T2i + Mw \times Twi$$

Substitution:

$$Tf \times (.092 \times 20 + 20) = .092 \times 20 \times 100 + 20 \times 20$$
$$21.84\ Tf = 584$$
$$Tf = 26.8\ °C$$

Solution for Aluminum ball:

Data:

$c3 = .211$ cal/g °C
$M3 = 20$ grams
$T3i = 100$ °C
$Mw = 20$ grams
$Twi = 20$ °C
$Tf = ?$

Basic Equation:

$$Tf \times (c3 \times M3 + Mw) = c3 \times M3 \times T3i + Mw \times Twi$$

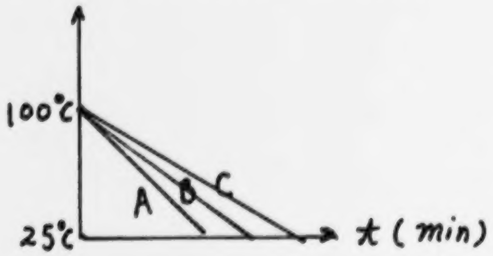
Substitution:

$$Tf \times (.211 \times 20 + 20) = .211 \times 20 \times 100 + 20 \times 20$$
$$24.22\ Tf = 822$$
$$Tf = 33.9\ °C$$

Correct Answer: 33.9 °C

25. There are three metal balls A, B, and C with the same mass. Consider they are drawn from a bottle of boiling water simultaneously and put on a desk. The temperature changes related to time are drawn as following figure.

Which ball has the largest specific heat?



Correct Answer: C

26. A metal block with a mass of 50 grams is warmed from 40 degrees to 100 degrees Celsius when it absorbs 330 calories of heat. Calculate the specific heat of the metal. Present it in terms of value and unit.

Value:____________________ Units:____________________

Solution:

Data:

M = 50 grams
Ti = 40 °C
Tf = 100 °C
Q = 330 cal
Cm = ?

Basic Equation:

Q = Cm x M x (Tf - Ti)

Substitution:

330 cal = Cm x 50 g x (100 - 40) °C
330 cal = Cm x 3000 g °C
Cm = .11 cal/g °C

Correct Answers: Value = .11, Unit = cal/g °C.

27. There are three kinds of liquid with the same mass. Liquid one is at 80 degrees, liquid two is at 30 degrees, and liquid three is at 10 degrees Celsius, respectively. Their specific heats are: (1) .60 cal/g °C, (2) .30 cal/g °C, and (3) .10 cal/g °C, respectively. Calculate the final temperature when the three liquids are combined into a single vessel.

Solution:

Data:

$M1 = M2 = M3 = M$
$c1 = .60$ cal/g °C
$Ti1 = 80$ °C
$c2 = .30$ cal/g °C
$Ti2 = 30$ °C
$c3 = .10$ cal/g °C
$Ti3 = 10$ °C
$Tf = ?$

Basic Equation:

$$Tf \times (c1 \times M + c2 \times M + c3 \times M) = c1 \times M \times Ti1 + c2 \times M \times Ti2 + c3 \times M \times Ti3$$

Substitution:

$$Tf \times (.60 + .30 + .10) \times M = (.60 \times 80 + .30 \times 30 + .10 \times 10) \times M$$

$$Tf = 58 \ ^\circ C$$

Correct Answer: 58 °C

28. Write the relationship among H (heat absorbed by a substance), M (mass of the substance), T (the temperature gained of the substance), and S (the specific heat of the substance).

Correct Answer: $H = M \; S \; T$

29. Heat transfer from or to a moving liquid or gas in which the motion is caused by the variations in density due to temperature change is called ______________.

Correct Answer: Convection

30. Heat transfer from one place to another place not requiring a physical medium is called ______________ .

Correct Answer: Radiation

31. In the following tables are presented the variation of temperature with time.

(A)

Time(hours)	0	2	4	6	8	10
Temp.(°C)	95	94	93	92	91	90

(B)

Time(minutes)	0	2	4	6	8	10
Temp. (°C)	90	91	92	93	94	95

(C)

Time(hours)	0	1	2	3	4	5
Temp.(°C)	24	25	26	27	28	29

(D)

Time(hours)	0	1	2	3	4	5
Temp. (°C)	29	28	27	26	25	24

Chose the proper table to relate the following items.

(a) A thermos bottle: ______, (b) Heating tube: ______,

(c) Day time:_______ , (d) Night time: _______.

Correct Answers: (a): A, (b): B, (c): C, (d): D.

32. Classify the items A to G into conductors or insulators.

(A) copper, (B) iron, (C) wood, (D) plastic,
(E) cloth (F) wool, (G) glass, (H) alumimun.

Correct Answer: Conductors: (A), (B), (H).
Insulator: (C), (D), (E), (F), (G).

33. Identify the items from A to D into the categories (1) to (3) as following.

(A) pan (B) heating bottle (C) air condition (D) electric heater.

(1) Conduction: ________

(2) Convection: __________

(3) Radiation: __________

Correct Answers: (1) Conduction: A, B.
(2) Convection: B, C.
(3) Radiation: D.

34. How much heat is required, in calories, to heat 2.52 kilograms of water from 77 degrees to 95 degrees Fahrenheit?

Solution:

Data: $Ti = 77\ ^\circ F$
$Tf = 75\ ^\circ F$
$M = 2.52$ Kgrams = 2520 grams
$Q = ?$

Basic Equation:

$$Q = M\,(Tf - Ti)$$

Substitution:

$$Tf - Ti = (95 - 77)\ ^\circ F = (35 - 25)\ ^\circ C$$

$$Q = 2520 \times 10 = 25200 \text{ cal.}$$

Correct Answer: 25200 cal

35. Consider heating 40 grams of water, from 20 degrees to 50 degrees Celsius. If the same amount of heat is absorbed by 40 grams of copper initially at 20 degrees and having specific heat of .092cal/g °C, calculate the final temperature of the copper.

Solution:

Data:

$M_w = 40$ grams
$T_{wi} = 20$ °C
$T_{wf} = 50$ °C
$M_c = 40$ grams
$T_{ci} = 20$°C
$C_c = .092$ cal/g °C
$T_{cf} = ?$

Basic Equation:

$$Q_w = Q_c$$
$$M_w \times (T_{wf} - T_{wi}) = C_c \times M_c \times (T_{cf} - T_{ci})$$

Substitution:

$$40\,(50 - 20) = .092 \times 40 \times (T_{cf} - 20)$$
$$1200 = 3.68\,T_{cf} - 73.6$$
$$T_{cf} = 346.1\ ^\circ C$$

Correct Answer: 346.1 °C

36. 30 grams of water at 60 degrees Celsius is mixed with water at 20 degrees. The final temperature of the mixture is 40 degrees. Calculate the mass of the cool water.

Solution:

Data:

$Mw1 = 30$ grams
$Tw1i = 60\ ^\circ C$
$Tf = 40\ ^\circ C$
$Tw2i = 20\ ^\circ C$
$Mw2 = ?$

Basic Equation:

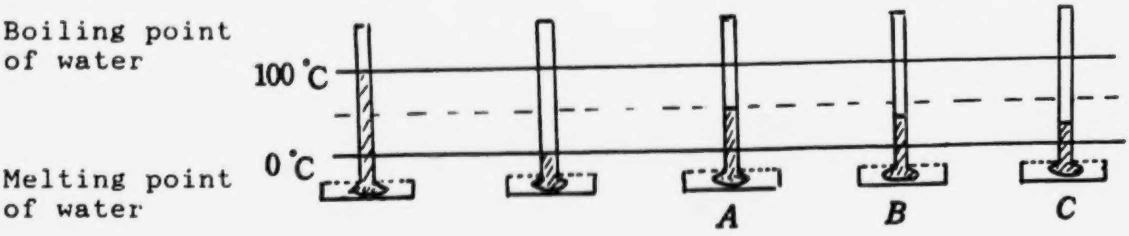
$$Tf \times (Mw1 + Mw2) = Tw1i \times Mw1 + Tw2i \times Mw2$$

Substitution:

$40\ (30 + Mw2) = 60 \times 30 + 20\ Mw2$
$1200 + 40\ Mw2 = 1800 + 20\ Mw2$
$20\ Mw2 = 600$
$Mw2 = 30$ grams

Correct Answer: 30 grams

37. In the following diagrams are presented the measured temperatures. Identify the correct diagram for the following items (1), (2), and (3) below.



(1) Body temperature:__________

(2) 50 degrees in Celsius:__________

(3) Room temperature:__________

Correct Answers: (1): C,
(2): A,
(3): B.

38- 40

Equal quantities of water, alcohol, and mercury having specific heats of 1.00, .60, and .033, respectively are heated from 25 to 75 degrees Celsius. Answer questions 38, 39, and 40 about this system.

38. If the same conditions are set, which liquid first reaches a temperature of 75 degrees Celsius?

Correct Answer: Mercury

39. Consider the three cups of liquid are at 75 degrees Celsius. Which one has the largest average molecular kinetic energy?

Correct Answer: The same.

40. If the same conditions are set, and the liquids cool down, which liquid is the first to drop from 75 to 25 degrees Celsius?

Correct Answer: Mercury

- End of Test -

APPENDIX C

THE MODULE

This appendix provides the details of the CAG module. The printed materials were included if the reproduced permissions were released from the publishers. If no permission was obtained a bibliographic reference was included. References for all the activities are listed at the end of Appendix C and in the main bibliography. Activities are listed by title of the activity and by authors of the book with each activity. The content of tables of the activities are listed as follows:

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(3) Section 13. 1-2: Temperature Is a Measure of Average Kinetic Energy 212

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APPENDIX C

Activity 13-(1-9)

Building a "Heat Measure" (Burkman, et al. 1981).*

EQUIPMENT

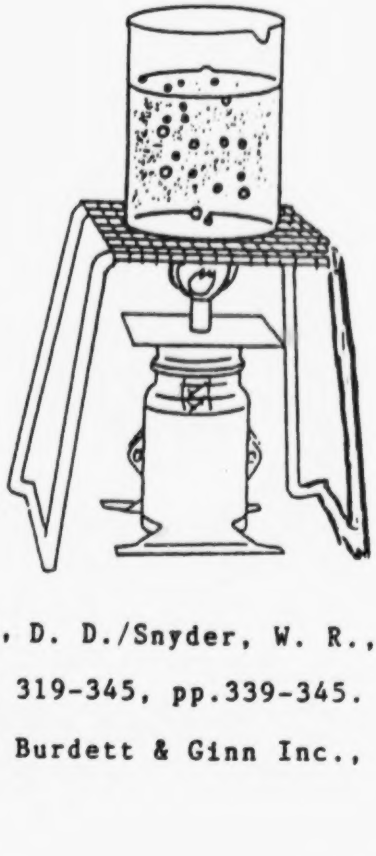
For Student

Water
1 100-ml beaker
1 alcohol burner
1 heating stand
1 wire screen
1 tongue depressor
1 large test tube
1 1-hole rubber stopper (to fit test tube)
1 plastic straw
2 rubber bands
1 wax pencil
1 Styrofoam cup (filled with crushed ice and water)

ACTIVITY 13-1. Fill the 100-ml beaker ¾ full of water. Then place the beaker on the heating stand, over the lighted alcohol burner.

☐ 13-1. What form of energy do you associate with temperature changes?

☐ 13-2. What idea does your answer to question 13-1 suggest about where energy "lost" in a converter goes?



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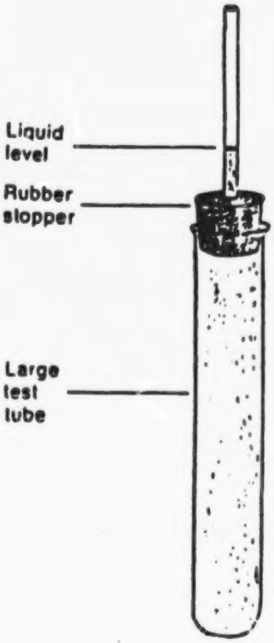
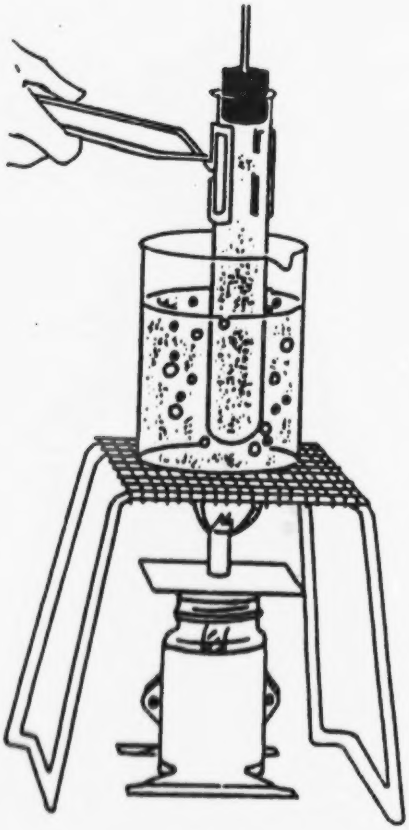
* Burkman, E./Darrow, S. P./Redfield, D. D./Snyder, W. R., The Natural World/1, (c)1981, pp. 319-345, pp.339-345. Reprinted by permission of Silver Burdett & Ginn Inc., Morristown, New Jersey.

ACTIVITY 13-2. Fill the large test tube with water to the top. Push the plastic straw through the stopper until it is even with the bottom. You might have to put a little oil on the straw. Push the stopper into the test tube. The liquid should rise a short distance into the straw.



ACTIVITY 13-3. Place the tube in a beaker of boiling water for 30 seconds. Notice the height of the liquid, then leave the tube in the boiling water 30 seconds longer.



☐ 13-3. What happened to the liquid in the tube?

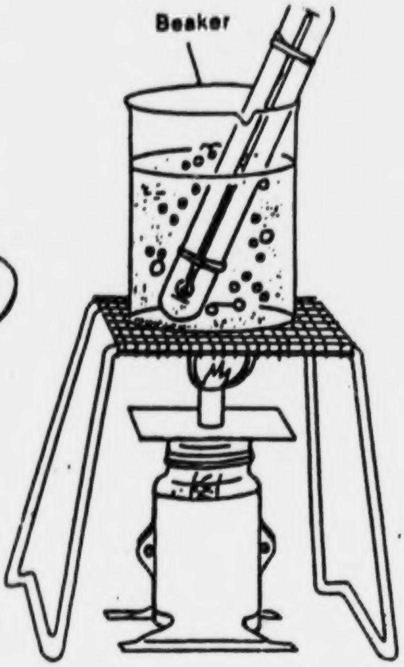
☐ 13-4. How did the effect on the liquid after 30 seconds compare with the effect after 60 seconds?

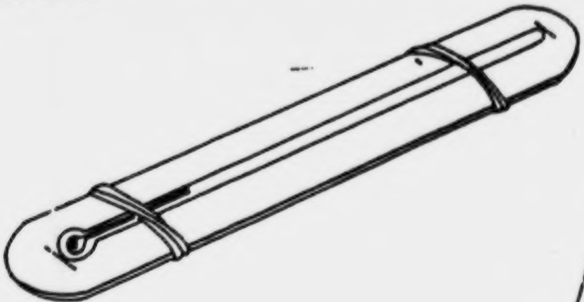
☐ 13-5. Does expansion appear to be a good property on which to base a heat measure?

☐ 13-6. What would you have to add to your thermometer to make it useful?

☐ 13-7. Describe how you could make the change you called for in question 13-6.

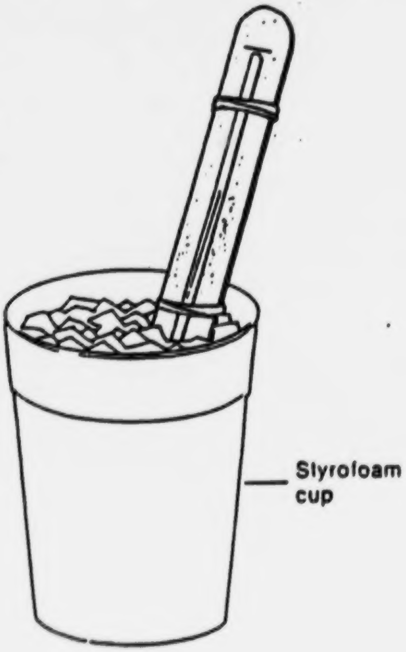
ACTIVITY 13-4. Fasten your thermometer firmly to a tongue depressor. Make a pencil mark on the tongue depressor at each end of the thermometer. Put it, bulb end down, in the boiling water. When the liquid in the tube stops rising, immediately mark the level on your tongue depressor. Then dry off the thermometer and use a wax pencil to mark the level on the glass tube.





ACTIVITY 13-5. Put the thermometer, bulb end down, in the Styrofoam cup containing crushed ice and water. Only the bulb should be under water. When the liquid in the thermometer stops falling, mark the level on the tongue depressor with a pencil. Then quickly dry off the thermometer and mark the same level on the glass tube with a wax pencil.

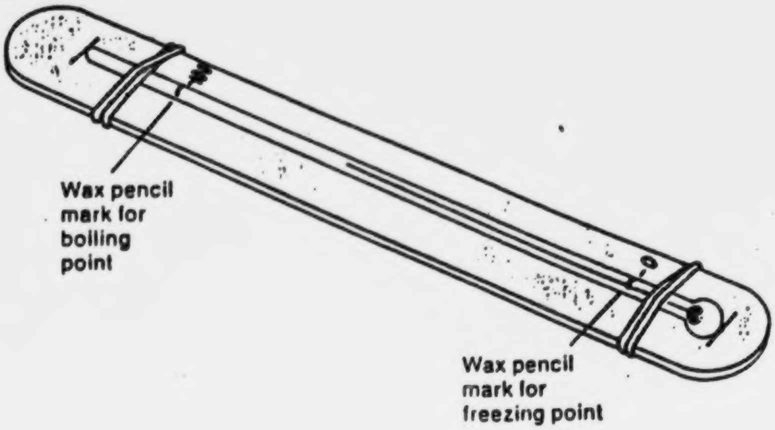
Allow the thermometer to return to room temperature. Then again measure the temperature of the ice water and of the boiling water.



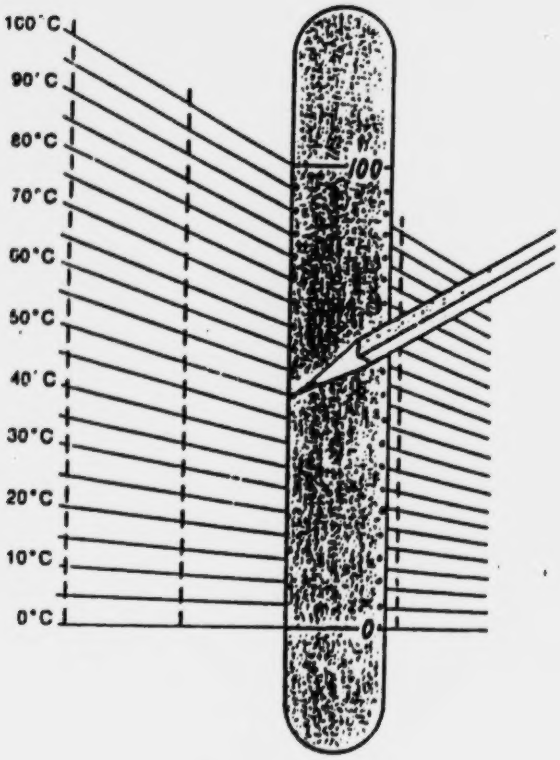
☐ **13-8.** Did the liquid stop at the same levels as before?

ACTIVITY 13-6. Label your lower mark "0." Label your upper mark with any number you wish. Using these marks you will set up your own scale. Mark off your scale on the tongue depressor. Don't write on the tube of your thermometer. Be sure to use a sharp lead pencil (not a wax pencil).

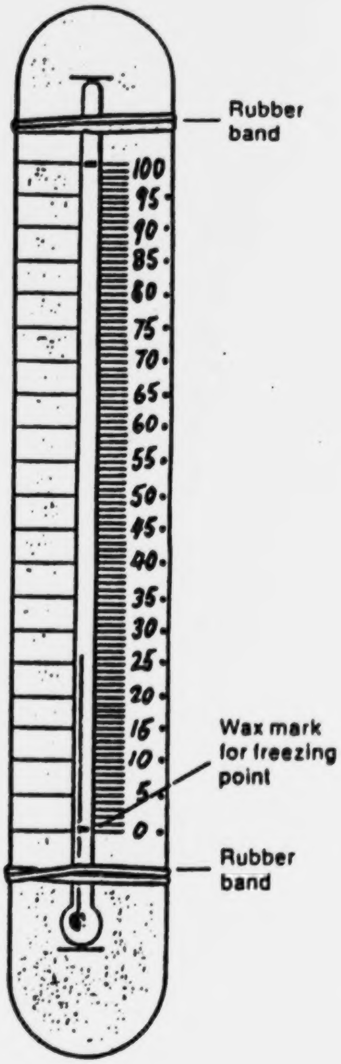
ACTIVITY 13-7. Label your mark for the boiling point "100." No scale lines or numbers should appear between these marks.


Wax pencil mark for boiling point
Wax pencil mark for freezing point

ACTIVITY 13-8 Move your tongue depressor to the right until the left end of the "100" line just touches the top line of the diagram. Mark the left edge of the tongue depressor next to each slanted line.


100°C
90°C
80°C
70°C
60°C
50°C
40°C
30°C
20°C
10°C
0°C
100
0

ACTIVITY 13-9 Divide the space between each pair of lines into 5 equal parts. This means only 4 pencil marks. Now draw the lines as shown.


Rubber band
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Wax mark for freezing point
Rubber band

Section 13. 1-1

Temperature (Ewen, et al. 1988)*

An understanding of temperature and heat is very important to all technicians. An automotive technician is concerned with the heat energy released by a fuel mixture in a combustion chamber. [illegible]. The excess heat produced by an engine must be transferred to the atmosphere. The highway technician is concerned with the expansion of bridges and roads when the temperature changes.

Basically, temperature is a measure of the hotness or coldness of an object. Temperature could be measured in a simple way by using your hand to sense the hotness or coldness of an object. However, the range of temperatures which your hand can withstand is too small, and your hand is not precise enough to measure temperature. Therefore, other methods are used for measuring temperature.

We use the fact that certain properties of matter vary with their temperature. For example, when objects are heated, they give off light of different colors. When an object is heated, in the absence of chemical reactions, it first gives off red light. As it is heated more, it appears white (see Fig. 13-1).

Chemical reactions sometimes cause different colors to be given off. When carbon steel is heated and exposed to air, several colors are given off before it appears red. This is due to a chemical reaction involving the carbon. If we could measure the color of the light given off, we could then determine the temperature. Although this works only for high temperatures, it is used in the production of metal alloys. The temperature of hot molten metals is determined this way.

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* Dale Ewen/ Ronald J. Nelson/Neill Schurter, PHYSICS FOR CAREER EDUCATION, 3e,(c)1988,pp.252-265. Reprinted by permission of Prentice Hall, Inc., Englewood Cliffs, New Jersey.

Section 13. 1-2

Temperature Is a Measure of Average Kinetic Energy (Williams, et al. 1979).

No release received. See pp.99-100 in original publication.

Section 13. 1-3

What Happens When an Object Takes in Heat?

(Williams, et al. 1979; Ewen, et al. 1988)

This section contained materials from two sources. Source one (Williams, et al. pp. 100-101) was not released. Source two (Ewen, et al. 1988) was released. The materials from source two are as follows:

Another property of matter that we use to find temperature is that the volume of a liquid or a solid changes as its temperature changes. The liquid in glass thermometers is an example. This type of thermometer (Fig. 13-2) consists of a hollow glass bulb and a hollow glass tube joined together. A small amount of liquid mercury or alcohol is placed in the bulb. The air is removed from the tube. When the liquid is heated, it expands and rises up the glass tube. The height to which the liquid rises indicates the temperature.

Most solids expand when heated and contract when cooled. They expand or contract in all three dimensions—length, width, and thickness. When a solid is heated, the expansion is due to the increased length of the vibrations of the atoms and molecules. This results in the solid expanding in all directions. This increase in volume results in a decrease in weight density, which is discussed in Chapter 11. Engineers, technicians, and designers must know the effects of thermal expansion. You have no doubt heard of highway pavements buckling on a hot summer day (Fig. 13-4). Bridges are built with special joints that allow for expansion and contraction of the bridge deck. [illegible]. The clicking noise of a train's wheels passing over the rails can be heard more in winter than in summer. The space between rails is larger in winter than in summer. [illegible] If the rails were placed snugly end to end in the winter, they would buckle in the summer. Similarly, TV towers, pipelines, and buildings must be designed and built to allow for this expansion and contraction.

Figure 13-4 Thermal expansion causes pavement to break up in the summer.

Section 13. 1-4

Exchange of Temperature Scales (Ewen, et al. 1988)

There are four temperature scales which we will study (see Fig. 13-5) On the **Fahrenheit scale**, the ice point is 32°F and the boiling point is 212°F. When we write a certain temperature, we give a number, then the degree symbol (°) and a capital letter which indicates the scale. The letter F following the degree symbol is not to be considered as a unit when working problems. Temperatures below zero on a scale are written as negative numbers. Thus, 30° below zero on the Fahrenheit scale is written as −30°F.

The metric temperature scale is the **Celsius scale**, which has replaced the centigrade scale. The ice point is 0°C and the boiling point is 100°C. The relationship between Fahrenheit temperatures (T_F) and Celsius temperatures (T_C) is as follows:

$$T_F = \frac{9T_C}{5} + 32^\circ$$

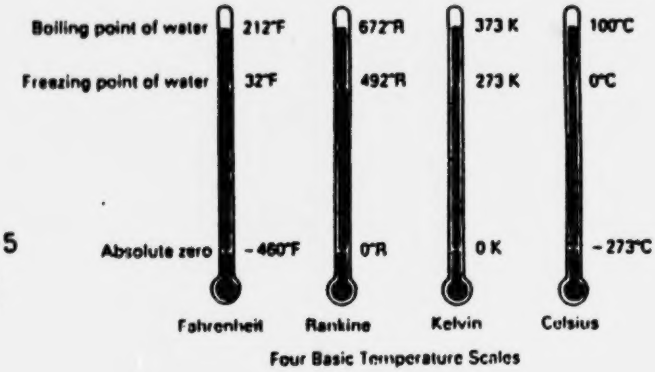

Boiling point of water
Freezing point of water
Absolute zero
212°F
32°F
−460°F
672°R
492°R
0°R
373 K
273 K
0 K
100°C
0°C
−273°C
Fahrenheit
Rankine
Kelvin
Celsius
Four Basic Temperature Scales

Figure 13-5
Four basic temperature scales.

In some technical work it is necessary to use the *absolute temperature scales*, which are the Rankine scale and the Kelvin scale. These are called absolute scales because 0 on either scale refers to the lowest limit of temperature, called absolute zero. Absolute zero and lower temperatures can never be attained. The reasons are discussed in the next section. There is no such limit on high temperatures.

The **Rankine scale** is closely related to the Fahrenheit scale. The relationship is

$$T_R = T_F + 460^\circ$$

The **Kelvin scale** is closely related to the Celsius scale. The relationship is*

$$T_K = T_C + 273$$

EXAMPLE 1

The average human body temperature is 98.6°F. What is it in Celsius?

Data:

$$T_F = 98.6°\text{F}$$
$$T_C = ?$$

Basic Equation:

$$T_C = \frac{5(T_F - 32°)}{9}$$

Working Equation: Same

Substitution:

$$T_C = \frac{5(98.6° - 32°)}{9}$$
$$= \frac{5(66.6°)}{9}$$
$$= 37.0°\text{C}$$

EXAMPLE 2

Change 535°R to degrees Fahrenheit.

Data:

$$T_R = 535°\text{R}$$
$$T_F = ?$$

Basic Equation:

$$T_R = T_F + 460°$$

Working Equation:

$$T_F = T_R - 460°$$

Substitution:

$$T_F = 535° - 460°$$
$$= 75°\text{F}$$

EXAMPLE 3

Change 18°C to Kelvin.

Data:

$$T_C = 18°C$$
$$T_K = ?$$

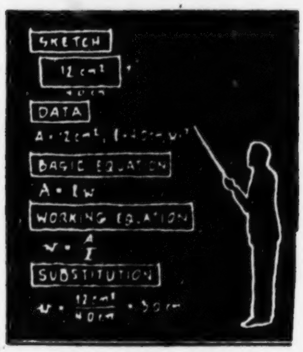
Basic Equation:

$$T_K = T_C + 273$$

Working Equation: Same

Substitution:

$$T_K = 18 + 273$$
$$= 291 \text{ K}$$


SKETCH
12 cm²
4.0 cm
DATA
A = 12 cm², l = 4.0 cm, w = ?
BASIC EQUATION
A = lw
WORKING EQUATION
w = A/l
SUBSTITUTION
w = 12 cm²/4.0 cm = 3.0 cm

Problems for Sections 13. 1-(1-4)

1. The temperature in a crowded room is 85°F. What is the Celsius reading?
2. The temperature of an ice tea drink is 5°C. What is the Fahrenheit reading?
3. The boiling point of liquid nitrogen is −196°C. What is the Fahrenheit reading?
4. The melting point of ethyl alcohol is −179°F. What is the Celsius reading?

During the forging and heat-treating of steel, the color of heated steel is used to determine its temperature. Complete the following table, which shows the color of heat-treated steel and the corresponding approximate temperatures in Celsius and Fahrenheit. (Round to three significant digits.)

	Color	°C	°F
5.	White	____	2200
6.	Yellow	1100	____
7.	Orange	____	1725
8.	Cherry red	718	____
9.	Dark red	635	____
10.	Faint red	____	900

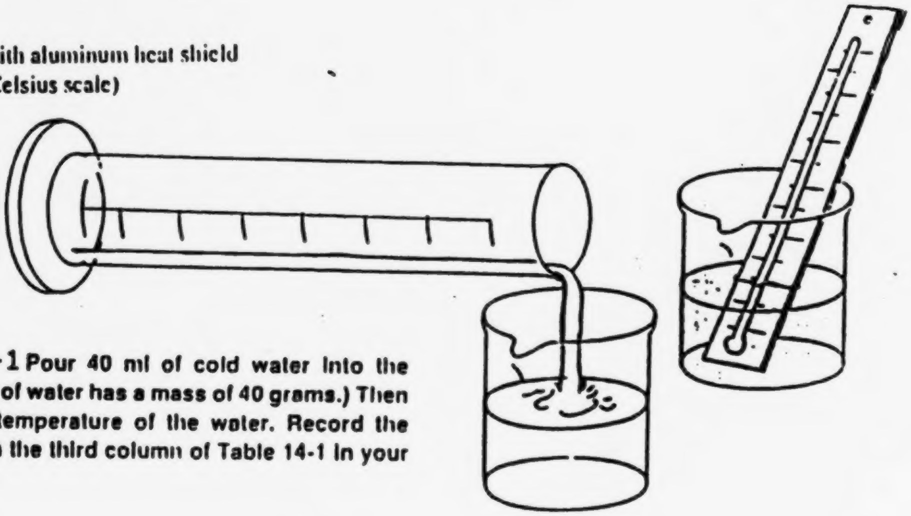
Activity 14-(1-2)

Getting into Hot Water

(Burkman, et al. 1981)

Equipment

- 1 100-ml graduated cylinder
- 1 100-ml beaker
- 1 alcohol burner
- 1 burner stand, with aluminum heat shield
- 1 thermometer (Celsius scale)



ACTIVITY 14-1 Pour 40 ml of cold water into the beaker. (40 ml of water has a mass of 40 grams.) Then measure the temperature of the water. Record the temperature in the third column of Table 14-1 in your Record Book.

Table 14-1

Heating time(min)	Mass of water (gram)	Initial T. (°C)	Final T. (°C)	ΔT (°C)	Heat Added

☐ **14-1.** Did the water absorb the same amount of heat in all three trials?

☐ **14-2.** Why did you answer question 14-1 as you did?

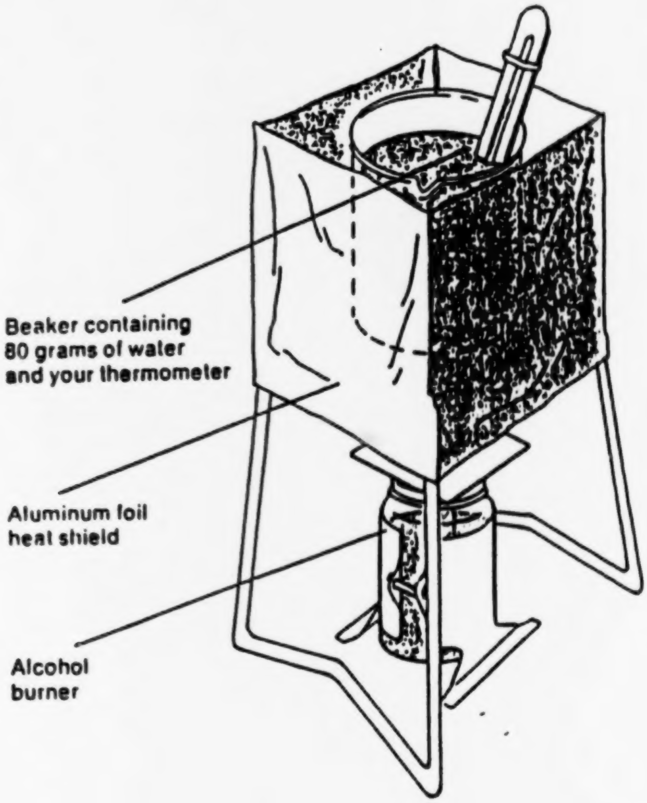
☐ **14-3.** Was the *change* in the thermometer readings the same for all three trials?

☐ **14-4.** Does the same amount of heat always cause the same change in thermometer readings?

☐ **14-5.** Did your thermometer measure the amount of *heat* in these experiments?

ACTIVITY 14-2. A. You are going to heat the water for exactly 4 minutes. Light the alcohol burner. When you are ready to time the heating carefully, put the foil-covered heating stand over it. Arrange your apparatus as shown.

B. After 4 minutes, read and record the water temperature. Then remove the heat and allow the beaker to cool. Repeat Activities 14-2 and 14-3 for 60 ml and 80 ml of water. Record your data in Table 14-1.


Beaker containing
80 grams of water
and your thermometer
Aluminum foil
heat shield
Alcohol
burner

☐ **14-6.** What is the mass in grams of 40 milliliters of water? of 60 milliliters of water? of 80 ml of water?

To calculate the amount of heat added to the water, use the following equation.

$$\text{Mass of water} \times \text{Temperature change} = \text{Amount of heat added to the water}$$

This formula gives you the operational definition for heat that you have been searching for.

☐ **14-7.** Suppose you calculated the amount of heat for each trial in Table 14-1. Would you predict that the amounts of heat would be the same? Why do you think so?

☐ **14-8.** Were your calculations of heat about the same for each trial? Have your teacher check your results and initial Table 14-1 in your Record Book.

☐ **14-9.** Adding an equal amount of heat to different amounts of water produces different temperature changes. How does the heat-substance model explain this?

Section 13. 2-1

Heat (Ewen, et al. 1988)

When a machinist drills a hole in a metal block (Fig. 13.5), it becomes very hot. As the drill does mechanical work on the metal, the temperature of the metal increases. How can we explain this? We need to look at the difference between the metal at low temperatures and at high temperatures. At high temperatures the atoms in the metal vibrate more rapidly than at low temperatures. Their velocity is higher at high temperatures, and thus their kinetic energy (KE $= \frac{1}{2}mv^2$) is greater. To raise the temperature of a material, we must speed up the atoms; that is, we must add energy to them. **Heat** *is the name given to this energy which is being added to or taken from a material.*

Drilling a hole in a metal block causes a temperature increase. As the drill turns, it collides with atoms of the metal, causing them to speed up. This mechanical work done on the metal has caused an increase in the energy (speed) of the atoms. For this reason, any friction between two surfaces results in a temperature rise of the materials.

Since heat is a form of energy, we could measure it in ft lb or joules, which are energy units. However, it was not always known that heat was a form of energy, and special units for heat were developed and are still in use. These units are the Btu (British thermal unit) in the English system and the calorie and the kilocalorie in the metric system. The Btu is the amount of heat (energy) necessary to raise the temperature of 1 lb of water 1°F. The calorie (cal) is the amount of heat (energy) necessary to raise the temperature of 1 gram of water 1°C. The kilocalorie (kcal) is the amount of heat necessary to raise the temperature of 1 kilogram of water 1°C. *Note:* One food calorie is the same as 1 kilocalorie.

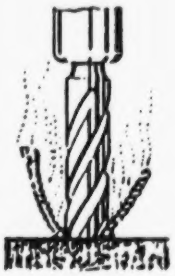
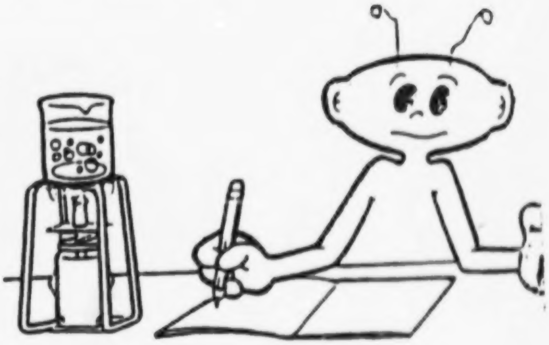


Figure 13.5
Friction causes a rise in temperature of the drill and plate.

Section 13. 2-2

What Is a Calorie? (Burkman, et al. 1981)



When scientists still used the heat-substance model for heat, they named the heat substance *caloric*. This was a natural thing for them to do. The old Latin word for heat was *calor*. They just added two letters to the end of the word (*ic* means "of").

Then scientists found that they could measure the amount of heat that goes into water. All they had to do was multiply the mass by the temperature change. When they needed a unit to measure heat, it was again natural for them to form the word *calorie*.

Today, scientists use the term *calorie* as the amount of heat it takes to raise the temperature of 1 gram of water 1 Celsius degree. This is an operational definition for heat. Expressed as an equation:

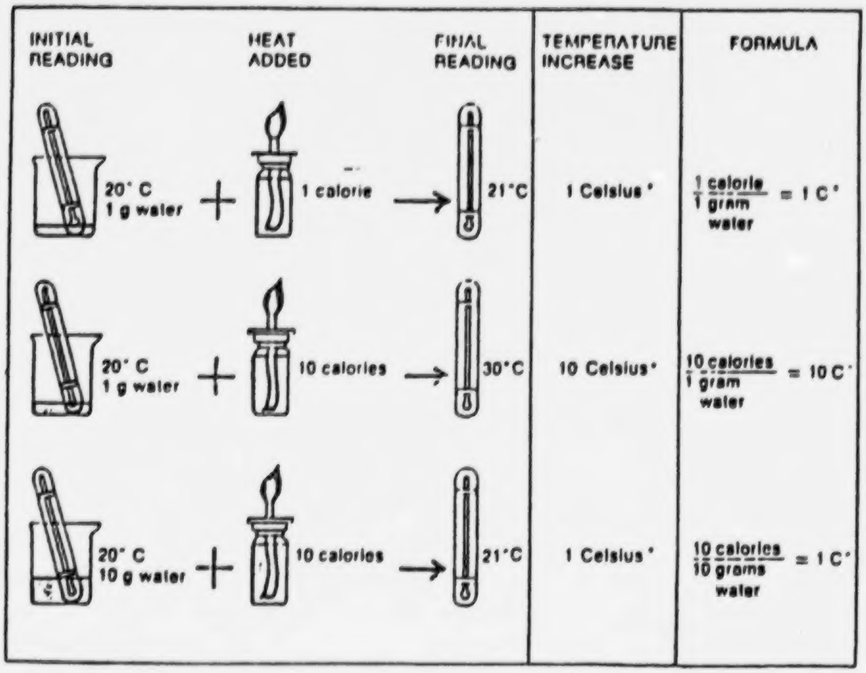
$$\text{Calories of heat} = \text{Grams of water} \times \text{Change in temperature in Celsius degrees}$$

This is the same thing as:

$$\text{Change in temperature in Celsius degrees} = \frac{\text{Calories of heat}}{\text{Grams of water}}$$

Look at the situations illustrated in Figure 1. See if you can use this idea to answer a few questions. Remember that 10° Celsius (or 10 degrees Celsius) is a definite temperature. But 10 Celsius° (or 10 Celsius degrees) does not mean a definite temperature. It means a difference between two temperatures—say, between 20° Celsius and 30° Celsius.

Figure 1


INITIAL READING
HEAT ADDED
FINAL READING
TEMPERATURE INCREASE
FORMULA
20° C 1 g water
1 calorie
21°C
1 Celsius°
$\frac{1 \text{ calorie}}{1 \text{ gram water}} = 1\ C°$
20° C 1 g water
10 calories
30°C
10 Celsius°
$\frac{10 \text{ calories}}{1 \text{ gram water}} = 10\ C°$
20° C 10 g water
10 calories
21°C
1 Celsius°
$\frac{10 \text{ calories}}{10 \text{ grams water}} = 1\ C°$

Section 13. 2-3

Conservation of Energy (Ewen et al. 1988)

As we saw above, heat and work are somehow related. James Prescott Joule (1818–1889), an English scientist, determined by experiments the relationship between heat and work. He found that

1. 1 cal of heat is produced by 4.19 J of work.
2. 1 kcal of heat is produced by 4190 J of work.
3. 1 Btu of heat is produced by 778 ft lb of work.

These relationships are known as the mechanical equivalent of heat.

Of the many examples by which heat is converted into useful work, we present the following:

1. ***In our bodies.*** When food is oxidized, heat energy is produced which can be converted into muscular energy, which in turn can be turned into work. Experiments have shown that only about 25% of the heat energy from our food is converted into muscular energy. That is, our bodies are about 25% efficient.
2. ***By burning gases.*** When a gas is burned, the gas expands and builds up a tremendous pressure which may convert heat to work by exerting a force to move a piston or turn the blades of a turbine. Since the burning of the fuel occurs within the cylinder or turbine, such engines are called *internal combustion engines.*
3. ***By steam.*** Heat from burning oil, coal, or wood may be used to generate steam. When water changes to steam under normal atmospheric pressure, it expands about 1700 times. When confined to a boiler, the pressure exerts a force against the piston in a steam engine or against the blades of a steam turbine. Since the fuel burns outside the engine, most steam engines or steam turbines are *external combustion engines.*

Technically, what is the difference between temperature and heat? Temperature is a measure of the average velocity of the molecules in a substance. Heat is the total thermal energy (kinetic and potential) that is added to or taken away from the molecules in a substance. There are two basic ways of changing the temperature of an object:

1. By doing work *on* the substance, such as the work done by the drill on the metal block in Fig. 13.5
2. By supplying energy *to* the object, such as mechanical, chemical, or electrical

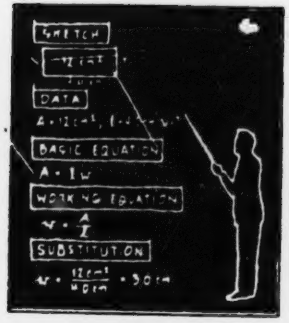
Section 13. 2-4

Heat Is Made up of Internal Energies

(Williams, et al. 1979)

No release received. See pp. 98-99 in original publication.

Problems for Sections 13. 2-(1-4)



☐1.

Find the amount of heat in cal generated by 95 J of work.
Find the amount of heat in kcal generated by 7510 J of work.
Find the amount of work that is equivalent to 1550 Btu.
Find the amount of work that is equivalent to 3850 kcal.
Find the mechanical work equivalent (in J) of 765 kcal of heat.

☐2. 100 grams of water at 20° Celsius + 500 calories = 100 grams of water at what degree Celsius?

☐3. 1 kilogram (1,000 grams) of water at 20° Celsius + 2 kilocalories (2,000 calories) = how many grams of water at what degree Celsius?

☐4. You heated 40 grams of water with your alcohol burner. The temperature went from 20°C to 80°C. How many calories of heat did you add?

Section 13. 3-1

Heat Transfer (Ewen, et al. 1988)

The movement of heat from a hot engine to the air is necessary to keep the engine from overheating. The heat produced by a furnace is transferred to the various rooms in a house. The movement of heat is a major technical problem.

The transfer of heat from one object to another is always from the warmer object to the colder one or from the warmer part of an object to a colder part (Fig. 13.6). There are three methods of heat transfer: conduction, convection, and radiation. The usual method of heat transfer in solids is conduction. When one end of a metal rod is heated, the molecules in that end move faster than before. These molecules collide with other molecules and cause them to move faster also. In this way the heat is transferred from one end of the metal to the other (Fig. 13.7). Another example of conduction is the transferring of the excess heat produced in the combustion chamber of an engine through the engine block into the water coolant (Fig. 13.8).

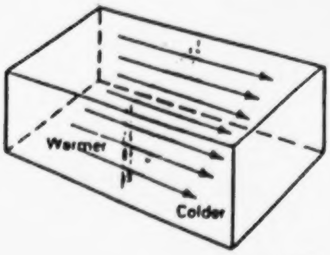


Figure 13.6
Transfer of heat from warmer to colder.

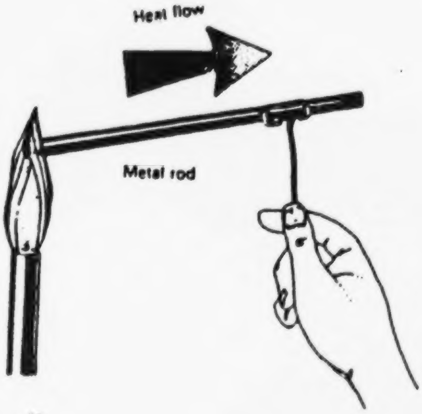


Figure 13.7
Heat flows by conduction in the metal rod.

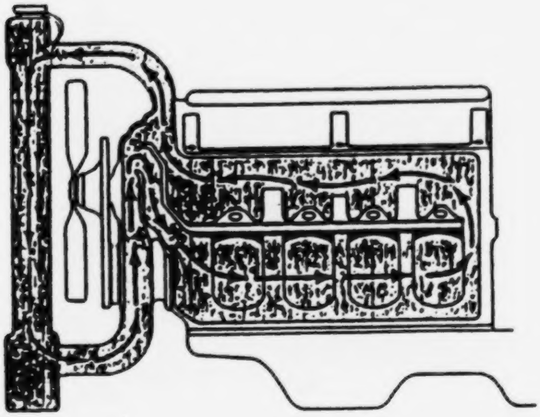


Figure 13.8
Heat conduction in an auto engine cooling system.

The conduction of heat through some materials is better than through others. A poor conductor of heat is called an insulator. A list of good conductors and poor conductors is given in Table 13.1.

Table 13.1 Good and Poor Heat Conductors

Good heat conductors	Poor heat conductors
Copper	Asbestos
Aluminum	Glass
Steel	Wood
	Air

Another method of heat transfer is called convection. This is the movement of warm gases or liquids from one place to another. The wind carries heat along with it. The water coolant in an engine carries hot water from the engine block to the radiator by a convection process. The wind is a natural convection process. The engine coolant is a forced convection process because it depends on a pump.

Convection currents are caused by the expansion of liquids or gases as they are heated or cooled. This expansion makes the hot gas or liquid less dense than the surrounding fluid. The lighter fluid is then forced upward by the heavier surrounding fluid, which then flows in to replace it (Fig. 13.9). This type of behavior occurs in a fireplace as hot air goes up the chimney and is replaced by cool air from the adjacent room. The

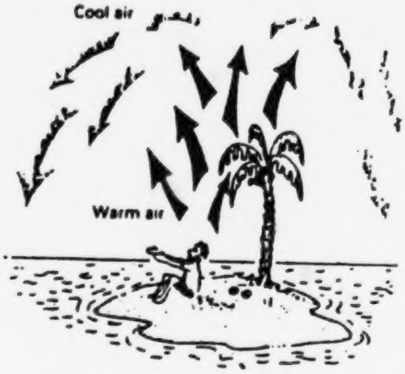


Figure 13.9
Heat convection.

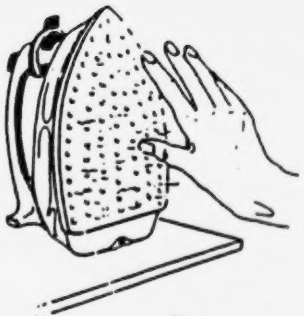
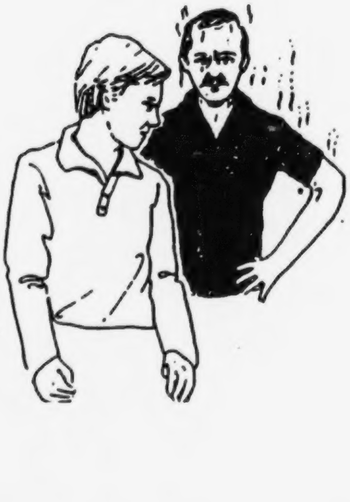


Figure 13.10
Heat radiation.

cool air draft, as this is called, is eventually supplied from outside air. This is why a fireplace is not very effective in heating a house. An airtight woodburning stove, however, draws little air from the inside of a house and is therefore much more efficient at heating the house.

The third method of heat transfer is radiation. Put your hand several inches from a hot iron (Fig. 13.10). The heat you feel is not transferred by conduction because air is a poor conductor. It is not transferred by convection because the hot air rises. This kind of heat transfer is called radiation. This radiant heat is similar to light and passes through air, glass, and the vacuum of space. The energy that comes to us from the sun is in the form of radiant energy. Dark objects absorb radiant heat and light objects reflect radiant heat. This is why we feel cooler on a hot day in light-colored clothing than in dark clothing (Fig. 13.11).

Figure 13.11
Dark objects absorb more radiant heat than light objects.



Section 13. 3-2

Controlling the Transfer of Heat (Brandwein, et al. 1980)

No release received. See pp. 245-246 in original publication.

Section 13. 3-3

Solar Heating (Brandwein, et al. 1980)

No release received. See pp. 246-247 in original Publication.

Problems for Sections 13. 3-(1-3)

1. What conditions are necessary in order to have thermal conduction from one end of a rod to another?
2. Why is heat transfer by convection limited to fluids?
3. It has been said that heat transfer by conduction and by convection supports the kinetic molecular theory of heat, but that heat transfer by radiation does not. Can you defend or oppose it?
4. Each of the following metal rods is warmed as indicated. Arrange them in order of increasing change in length;
   (1) An aluminum rod 6 meters long is raised 20 degrees Celsius.
   (2) A copper rod 3 meters long is raised 15 degrees Celsius.
   (3) The temperature of a steel rod 4.5 meters long is raised 15 degrees Celsius.
5. What is meant by the principle of heat exchange? How does it relate to the law conservation of energy?

Section 13. 4-1

Specific Heat (Ewen et al. 1988)

If we place a piece of steel and a pan of water in the direct sunlight, we would notice that the water becomes only slightly warmer while the iron gets quite hot. Why should one get so much hotter than the other? If equal masses of steel and water were placed over the same flame for 1 minute, the temperature of the steel would increase almost 10 times more than that of the water. The water has a greater capacity to absorb heat.

The specific heat of a substance is a measure of its capacity to absorb or give off heat per degree change in temperature. This property of water to absorb or give up large amounts of heat makes it an effective substance to transfer heat in industrial processes.

The specific heat of a substance is the amount of heat necessary to change the temperature of 1 lb 1°F (1 kg 1°C in the metric system). By formula,

$$c = \frac{Q}{w\,\Delta T} \quad \text{(English system)}$$

or

$$c = \frac{Q}{m\,\Delta T} \quad \text{(metric system)}$$

where c = specific heat
Q = heat
w = weight
m = mass
ΔT = change in temperature

These equations can be rearranged to give the amount of heat added or taken away from a material to produce a certain temperature change.

$$Q = c\,w\,\Delta T \text{ (English)}$$

$$Q = c\,m\,\Delta T \text{ (Metric)}$$

The heat constants of some materials are given as Table 15.

Table 15 Heat Constants

	Melting point (°C)	Boiling point (°C)	Specific heat cal/g°C or kcal/kg°C or Btu/lb°F	Specific heat J/kg°C	Heat of fusion cal/g or kcal/kg	Heat of fusion J/kg	Heat of vaporization cal/g or kcal/kg	Heat of vaporization J/kg
Alcohol, ethyl	−117	78.5	0.58	2400	24.9	1.04×10^5	204	8.54×10^5
Aluminum	660	2057	0.22	920	76.8	3.21×10^5		
Brass	840		0.092	390				
Copper	1083	2330	0.092	390	49.0	2.05×10^5		
Glass			0.21	880				
Ice	0		0.51	2100	$8\bar{0}$	3.35×10^5		
Iron (steel)	1540	3000	0.115	481	7.89	3.30×10^4		
Lead	327	1620	0.031	130	5.86	2.45×10^4		
Mercury	−38.9	357	0.033	140	2.82	1.18×10^4	65.0	2.72×10^5
Silver	961	1950	0.056	230	26.0	1.09×10^5		
Steam			0.48	$2\bar{0}00$				
Water (liquid)	0	$10\bar{0}$	1.00	4190			$54\bar{0}$	2.26×10^6
Zinc	419	907	0.092	390	23.0	9.63×10^4		

Example 1

A metal block of mass 100 grams is warmed from 30 degrees Celsius to 100 degrees Celsius when it absorbs 140 cal of heat energy. What is its specific heat?

Data: $M = 100$ grams

$\Delta T = 100\ ^{o}C - 30\ ^{o}C = 70\ ^{o}C$

$Q = 140$ cal

$c =$ specific heat $= ?$

Basic Equation:

$$c = \frac{Q}{M \Delta T} \simeq \frac{140 \text{ cal}}{100 \text{ g} * 70\ ^{o}C}$$

$$= .092 \text{ cal/g}^{o}c$$

Example 2

How many kilocalories of heat must be added to 10.0 kg of steel to raise its temperature $15\bar{0}$°C?

Data:

$m = 10.0$ kg

$\Delta T = 15\bar{0}$°C

$c = 0.115$ kcal/kg °C (from Table 15)

$Q = ?$

Basic Equation:

$$Q = cm\,\Delta T$$

Working Equation: Same

Substitution:

$$Q = 0.115 \frac{\text{kcal}}{\cancel{\text{kg}}\ \cancel{°\text{C}}} \times 10.0\ \cancel{\text{kg}} \times 15\bar{0}\ \cancel{°\text{C}}$$

$$= 173 \text{ kcal}$$

Example 3

How many joules of heat must be absorbed to cool 5.00 kg of water from 75.0°C to 10.0°C?

Data:

$$m = 5.00 \text{ kg}$$
$$\Delta T = 75.0^\circ\text{C} - 10.0^\circ\text{C} = 65.0^\circ\text{C}$$
$$c = 4190 \text{ J/kg }^\circ\text{C} \quad \text{(from Table 15)}$$
$$Q = ?$$

Basic Equation:

$$Q = cm\,\Delta T$$

Working Equation: Same

Substitution:

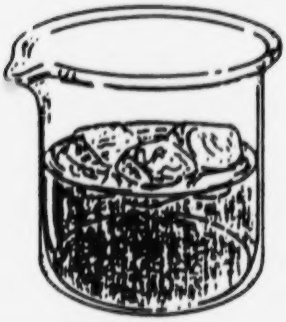
$$Q = 4190 \frac{\text{J}}{\cancel{\text{kg}}\ \cancel{^\circ\text{C}}} \times 5.00\ \cancel{\text{kg}} \times 65.0\ \cancel{^\circ\text{C}}$$
$$= 1.36 \times 10^6 \text{ J} \quad \text{or} \quad 1.36 \text{ MJ}$$

Section 13. 5-1

Method of Mixtures (Ewen, et al. 1988)

When two substances at different temperatures are "mixed" together, heat flows from the warmer body to the cooler body until they reach the same temperature (Fig. 13.12). Part of the heat lost by the hotter body is transferred to the colder body and part is lost to the surrounding objects or the air. In many cases most all the heat is transferred to the colder body. We assume that all the heat lost by the warmer body is transferred to the cooler body. That is, the heat lost by the warmer body equals the heat gained by the cooler body. The amount of heat lost or gained by a body is

Figure 13.12
Heat flows from the warmer substance to the cooler.



$$Q = cw\,\Delta T \quad \text{or} \quad Q = cm\,\Delta T$$

By formula,

$$Q_{\text{lost}} = Q_{\text{gained}}$$

$$c_l w_l (T_l - T_f) = c_g w_g (T_f - T_g)$$

where the subscript l refers to the warmer body which *loses* heat, the subscript g refers to the cooler body which *gains* heat, and T_f is the final temperature of the mixture.

Example 1

If $20\bar{0}$ g of steel at $22\bar{0}$°C is added to $50\bar{0}$ g of water at 10.0°C, find the final temperature of this mixture.

Data:

$c_l = 0.115$ cal/g°C $c_g = 1.00$ cal/g°C
$m_l = 20\bar{0}$ g $m_g = 50\bar{0}$ g
$T_l = 22\bar{0}$°C $T_g = 10.0$°C
$T_f = ?$

Basic Equation:

$$c_l m_l (T_l - T_f) = c_g m_g (T_f - T_g)$$

Working Equation:

$$T_f = \frac{c_l m_l T_l + c_g m_g T_g}{c_l m_l + c_g m_g}$$

Substitution:

$$T_f = \frac{(0.115\ \text{cal/g °C})(20\bar{0}\ \text{g})(22\bar{0}\text{°C}) + (1.00\ \text{cal/g °C})(50\bar{0}\ \text{g})(10.0\text{°C})}{(0.115\ \text{cal/g °C})(20\bar{0}\ \text{g}) + (1.00\ \text{cal/g °C})(50\bar{0}\ \text{g})}$$

$$= 19.2\text{°C}$$

To find T_f by the second method, substitute the data directly into the basic equation. Then, solve for T_f as follows:

$$0.115\,\frac{\text{cal}}{\text{g}\,^\circ\text{C}} \times 20\bar{0}\,\text{g}(22\bar{0}^\circ\text{C} - T_f) = 1.00\,\frac{\text{cal}}{\text{g}\,^\circ\text{C}} \times 50\bar{0}\,\text{g}(T_f - 10.0^\circ\text{C})$$

$$5060\,\frac{\text{cal}\,^\circ\text{C}}{^\circ\text{C}} - 23.0\,\frac{\text{cal}}{^\circ\text{C}}T_f = 50\bar{0}\,\frac{\text{cal}}{^\circ\text{C}}T_f - 50\bar{0}0\,\frac{\text{cal}\,^\circ\text{C}}{^\circ\text{C}}$$

$$10{,}060\,\text{cal} = 523\,\frac{\text{cal}}{^\circ\text{C}}T_f$$

$$\frac{10{,}060\,\cancel{\text{cal}}}{523\,\cancel{\text{cal}}/^\circ\text{C}} = T_f$$

$$19.2^\circ\text{C} = T_f$$

Example 2

A 10.0-lb piece of hot copper is dropped into 30.0 lb of water at 5$\bar{0}$°F. If the final temperature of the mixture is 65°F, what was the initial temperature of the copper?

Data:

$w_i = 10.0$ lb $\qquad w_w = 30.0$ lb

$c_i = 0.093$ Btu/lb °F $\qquad c_w = 1$ Btu/lb °F

$T_i = ?$ $\qquad T_w = 50$°F

$T_f = 65$°F

Basic Equation:

$$c_i w_i (T_i - T_f) = c_w w_w (T_f - T_w)$$

Working Equation:

$$T_i = \frac{c_w w_w}{c_i w_i}(T_f - T_w) + T_f$$

Substitution:

$$T_i = \frac{(1\ \text{Btu/lb}\,^\circ\text{F})(30.0\ \text{lb})}{(0.093\ \text{Btu/lb}\,^\circ\text{F})(10.0\ \text{lb})}(65^\circ\text{F} - 5\bar{0}^\circ\text{F}) + 65^\circ\text{F}$$
$$= 550^\circ\text{F}$$

Or, some find it easier to find T_i using a second method. Substitute the data directly into the basic equation. Then, solve for T_i as follows:

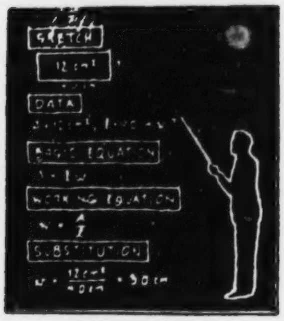
$$0.093\,\frac{\text{Btu}}{\text{lb}\,^\circ\text{F}} \times 10.0\,\text{lb}(T_i - 65^\circ\text{F}) = 1\,\frac{\text{Btu}}{\text{lb}\,^\circ\text{F}} \times 30.0\,\text{lb}(65^\circ\text{F} - 5\bar{0}^\circ\text{F})$$

$$0.93T_i\,\text{Btu}/^\circ\text{F} - 6\bar{0}\,\text{Btu} = 450\,\text{Btu}$$

$$0.93\,T_i\,\text{Btu}/^\circ\text{F} \quad 510\,\text{Btu}$$

$$T_i = \frac{510\,\cancel{\text{Btu}}}{0.93\,\cancel{\text{Btu}}/^\circ\text{F}}$$

$$T_i = 550^\circ\text{F}$$



Problems for Sections 13. 4-1 and 13. 5-1

Find Q for each material.

1. Steel, $w = 3.00$ lb, $\Delta T = 50\bar{0}$°F, Q = ________ Btu
2. Copper, $m = 155$ kg, $\Delta T = 17\bar{0}$°C, Q = ________ kcal
3. Water, $w = 19.0$ lb, $\Delta T = 20\bar{0}$°F, Q ________ Btu
4. Water, $m = 25\bar{0}$ g, $\Delta T = 17$°C, Q = ________ cal
5. Ice, $m = 5.00$ kg, $\Delta T = 2\bar{0}$°C, Q = ________ J
6. Steam, $w = 5.00$ lb, $\Delta T = 4\bar{0}$°F, Q = ________ Btu
7. Aluminum, $m = 79.0$ g, $\Delta T = 16$°C, Q = ________ cal
8. Brass, $m = 75\bar{0}$ kg, $\Delta T = 125$°C, Q = ________ J
9. Steel, $m = 1250$ g, $\Delta T = 50.0$°C, Q = ________ J
10. Aluminum, $m = 85\bar{0}$ g, $\Delta T = 115$°C, Q = ________ kcal
11. Water, $m = 80\bar{0}$ g, $\Delta T = 80.0$°C, Q = ________ kcal
12. Lead, $m = 475$ kg, $\Delta T = 245$°C, Q = ________ J

13. How many Btu's of heat must be added to 12$\bar{0}$0 lb of copper to raise its temperature from 10$\bar{0}$°F to 45$\bar{0}$°F?
14. How many Btu's of heat are given off by 50$\bar{0}$ lb of aluminum when it cools from 65$\bar{0}$°F to 75°F?
15. How many kcal of heat must be added to 1250 kg of copper to raise its temperature from 25°C to 275°C?
16. How many joules of heat are absorbed by an electric freezer in lowering the temperature of 1850 g of water from 80.0°C to 10.0°C?
17. How many joules of heat are required to raise the temperature of 75$\bar{0}$ kg of water from 15.0°C to 75.0°C?
18. How many kilocalories of heat must be added to 75$\bar{0}$ kg of steel to raise its temperature from 75°C to 30$\bar{0}$°C?
19. How many joules of heat are given off when 125 kg of steel cools from 1425°C to 82°C?
20. A 525-kg steam boiler is made of steel and contains 315 kg of water at 40.0°C. Assuming that 75% of the heat is delivered to the boiler and water, how many calories are required to raise the temperature of both the boiler and water to 100.0°C?

Activity 15 - (1-3)

Investigate the Specific Heat of an Unknown Metal

(Developed by the investigator)

Equipment

Water

1 100-ml beaker

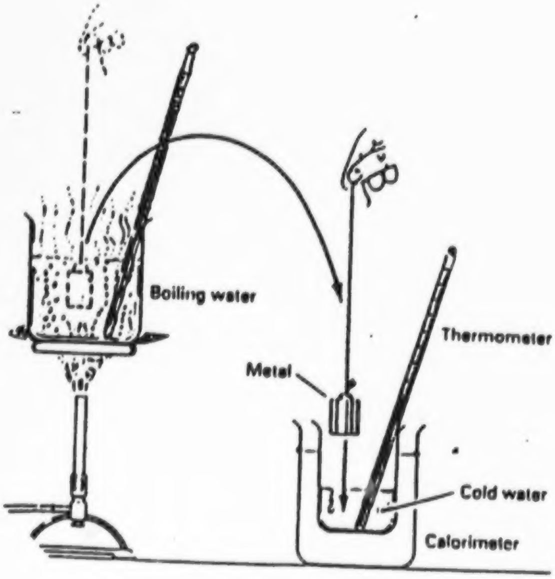
1 metal block

1 alcohol burner

2 thermometers

1 heating stand

1 wire sreen


Boiling water
Thermometer
Metal
Cold water
Calorimeter

Apparatus for measuring the specific heat of a metal by the method of mixtures.

Activity 15-1

Measure the mass of the metal block and put it into boiling water for 30 seconds. Mm = _____ grams.

☐ 15.1 What is the temperature of the metal block after 30 seconds in boiling water? Ti,m = ____ °C.

☐ 15.2 Can you explain your answer?

Activity 15-2

Measure the mass of the cold water and its initial temperature.

Mw = _____ grams, Tw,i = ______ °C.

☐ 15.3 What are the mass of the calorimeter and its specific heat?

Mc = ______ grams, Cc = ______ °C.

☐ 15.4 Why do you need to know the quantities asked by question 15.3?

Activity 15-3

Shift the metal block from boiling water to cold water and measure its temperature after 30 seconds. Tf = ____ °C.

☐ 15.5 Are the water, metal block, and calorimeter the same temperature after 30 seconds?

Explain your answer.

☐ 15.6 Could you apply the conservation of thermal energy in above situation? What is a useful equation to be used to calculate the specific heat of the metal block?

Write down the equation.

☐ 15.7 Can you substitute the values which you have measured into your equation and calculate specific heat of the unknown metal?

Example 1

Find the specific heat of the unknown metal.

The following data were collected in the laboratory to determine the specific heat of an unknown metal.

Mass of alumonum calorimeter	132 g
Specific heat of calorimeter	920 j/kg °C
Mass of water	285 g
Specific heat of water	4190 j/kg °C
Mass of metal	215 g
Initial temperature of water and calorimeter	12.6 °C
Initial temperature of metal	99.1 °C
Final temperature of calorimeter, water and metal	18.6 °C

Find the specific heat of the unknown metal.

Data:

$M_c = 132g = .132$ kg

$C_c = 920$ j/kg°C

$M_w = 285$ g $= .285$ kg

$M_m = .215$kg

$T_{i,w} = 12.6$ °C

$T_f = 18.6$ °C

$T_{i,m} = 99.1$ °C

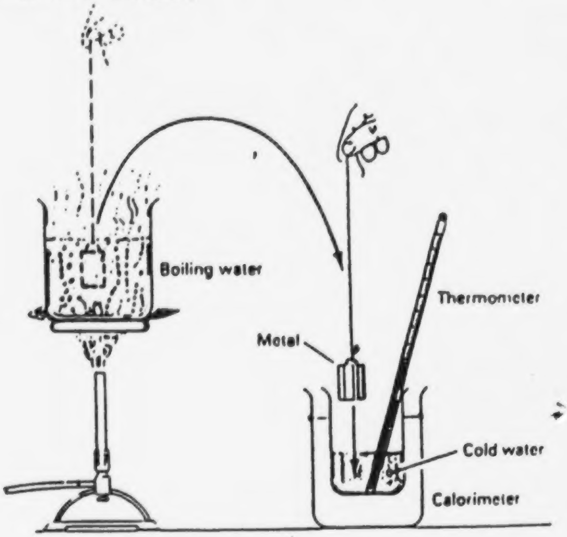


Figure 13.13
Apparatus for measuring the specific heat of a metal by the method of mixtures.

Basic Equation:

$$Cc\ Mc\ (\ Tf - Ti,w\ ) + Cw\ Mw\ (\ Tf - Ti,w\ ) = Cm\ Mm\ (Ti,m - Tf\ )$$

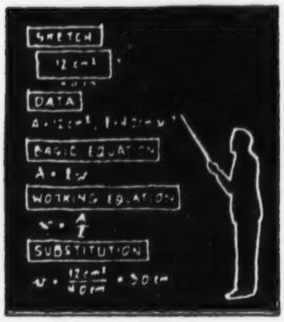
Solution:

$$920\ \text{j/kg}\ ^{o}\text{C} \times .132\ \text{kg}\ (18.6 - 12.6\ ) + 4190\ \text{j/kg}\ ^{o}\text{C} \times .285\ \text{kg}\ (18.6 - 12.6\ )\ ^{o}\text{C} = Cm \times .125\ \text{kg}\ (99.1 - 18.6)\ ^{o}\text{C}$$

$$724.64\ \text{j} + 7060.59\ \text{j} = Cm \times 17.3\ \text{kg}\ ^{o}\text{C}$$

$$Cm = \frac{7789.23}{17.3}\ \text{j/kg}\ ^{o}\text{C} = 450.24\ \text{j/kg}\ ^{o}\text{C}$$

Problems for Activities 15 - (1-3)



1. A 2.50-lb piece of steel is dropped into 11.0 lb of water at 75.0°F. The final temperature is 84.0°F. What was the initial temperature of the steel?
2. Mary mixes 5.00 lb of water at $20\bar{0}$°F with 7.00 lb of water at 65.0°F. What is the final temperature of the mixture?
3. A $25\bar{0}$-g piece of tin at 99°C is dropped in $10\bar{0}$ g of water at $1\bar{0}$°C. If the final temperature of the mixture is $2\bar{0}$°C, what is the specific heat of the tin?
4. How many grams of water at $2\bar{0}$°C are necessary to change $80\bar{0}$ g of water at $9\bar{0}$°C to $5\bar{0}$°C?
5. A 159-lb piece of aluminum at $50\bar{0}$°F is dropped into $40\bar{0}$ lb of water at $6\bar{0}$°F. What is the final temperature?
6. A 42.0-lb piece of steel at $67\bar{0}$°F is dropped into $10\bar{0}$ lb of water at 75.0°F. What is the final temperature of the mixture?
7. If 1250 g of copper at 20.0°C is mixed with $50\bar{0}$ g of water at 95.0°C, find the final temperature of the mixture.
8. If $50\bar{0}$ g of brass at $20\bar{0}$°C and $30\bar{0}$ g of steel at $15\bar{0}$°C are added to $90\bar{0}$ g of water in a $15\bar{0}$-g aluminum pan and both are at 20.0°C, what is the final temperature of this mixture assuming no loss of heat to the surroundings?
9. The following data were collected in the laboratory to determine the specific heat of an unknown metal.

Mass of copper calorimeter*	153 g
Specific heat of calorimeter	0.092 cal/g °C
Mass of water	275 g
Specific heat of water	1.00 cal/g °C
Mass of metal	236 g
Initial temperature of water and calorimeter	16.2°C
Initial temperature of metal	99.6°C
Final temperature of calorimeter, water and metal	22.7°C

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* A calorimeter is usually a metal cup inside another metal cup, which is insulated by the air between them (Fig. 13-13).

Reviewing the Concepts for the Module

(Brandwein, et al. 1980)

No release received. See pp.264-265 in original publication

References:

Brandwein, P. F., Yasso, W. E., & Brovey, D. J. (1980). Energy; A Physical Science: Concepts in Science. Curie Edition. Harcourt Brace Jovanovich Inc. (No release obtained)

Burkman, E., Darrow, S. P., Redfield, D. D., & Snyder, W. R. (1981). The Natural World/1. Silver Burdett Company, Morristown, New Jersey. (Release obtained)

Ewen, D., Nelson, R. J., & Schurter, N. (1988). Physics for Career Education; Third Edition, Prentice Hall Inc. (Release Obtained)

Williams, G. A., Barnes, R. A., Doerhoff, R. B., & Bolen, M. C. (1979). Physical Science; Challenges to Science; Second Edition; Webster Division, McGraw-Hill Book Company, New York. (No release obtained)

APPENDIX D

CORRELATION MATRICES OF MAJOR VARIABLES

This appendix provides Pearson correlation coefficients for the major variables in this study. The codes are as follows;

H1 to H19 present the item scores of prior knowledge in the pretest.

P1 to P8 present the item scores of Piagetian reasoning skills in the pretest.

CHINESE is the available scores of Chinese test.

MATHE. is the available scores of the mathematics test.

QP1 to QP40 are item scores of the posttest.

QF1 to QF40 are the item scores of the follow-up test.

F01 to F09 are the father's occupation (see Chapter 4).

M01 to M09 are the mother's occupation (see Chapter 4).

GROUP: the experimental group was coded as 1; the control group was coded as 2.

SEX: male was coded as 1, and female was coded as 2.

HSUM is the sum of the scores of prior knowledge on the pretest.

MSUM is the sum of scores of mathematics of the pretest

SUM is the sum of scores of the pretest.

PPSUM is the sum of scores of the posttest.

PFSUM is the sum of scores of the follow-up test.

INTERV: Interviewed students were coded as 1, other students were coded as 0.

OPCRT is the sum of scores of the concrete items of the posttest.

OPTRS is the sum of scores of the transitional items of the posttest.

OPFML is the sum of scores of the formal items of the posttest.

OFCRT is the sum of scores of the concrete items of the follow-up test.

OFTRS is the sum of scores of transitional items of the follow-up test.

OFFML is the sum of scores of the formal items of the follow-up test.

APPENDIX D

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P E A R S O N   C O R R E L A T I O N
C O E F F I C I E N T S

        GROUP       SEX         HSUM        MSUM        SUM

H1      .0088      -.0212       .3220       .1509       .2378
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .840     P= .624     P= .000     P= .000     P= .000

H2      .1742      -.1676       .4683       .2320       .3379
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .000     P= .000     P= .000     P= .000     P= .000

H3      .0289      -.0990       .2892       .0772       .1637
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .504     P= .022     P= .000     P= .074     P= .000

H4     -.0446      -.1124       .3450       .1148       .2382
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .303     P= .009     P= .000     P= .008     P= .000

H5      .0940      -.0450       .3016       .1301       .1824
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .029     P= .298     P= .000     P= .003     P= .000

H6     -.0236       .0779       .1154       .1120       .1009
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .585     P= .071     P= .007     P= .009     P= .019

H7     -.0451      -.0906       .2491       .0737       .1173
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .297     P= .036     P= .000     P= .088     P= .006

H8      .0873      -.0946       .2748      -.0289       .0687
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .043     P= .028     P= .000     P= .504     P= .112

H9     -.0736      -.0572       .3863       .3673       .4449
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .088     P= .185     P= .000     P= .000     P= .000

H10    -.0488      -.0585       .2449       .1242       .1109
      (  537)     (  537)     (  537)     (  537)     (  537)
      P= .259     P= .176     P= .000     P= .004     P= .010

 (COEFFICIENT / (CASES) / 2-TAILED SIG)
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-- PEARSON CORRELATION

        GROUP       SEX        HSUM       MSUM       SUM

H11     .0285      -.0765      .2587      .1717      .2127
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .510    P= .077    P= .000    P= .000    P= .000

H12     .0115      .0644      .1642      .0530      .0654
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .791    P= .136    P= .000    P= .220    P= .130

H13    -.1222     -.0817      .3530      .2566      .3206
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .005    P= .059    P= .000    P= .000    P= .000

H14    -.0309      .0161      .3435      .1513      .2178
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .475    P= .710    P= .000    P= .000    P= .000

H15     .0108     -.1260      .5050      .3289      .4517
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .803    P= .003    P= .000    P= .000    P= .000

H16     .1941     -.0384      .4943      .1486      .2624
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .000    P= .374    P= .000    P= .001    P= .000

H17     .1884     -.1093      .4074      .1215      .2523
         537)    (  537)    (  537)    (  537)    (  537)
      P= .000    P= .011    P= .000    P= .005    P= .000

H18     .1825     -.0079      .4239      .1458      .2080
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .000    P= .855    P= .000    P= .001    P= .000

H19    -.0282     -.0861      .4754      .3289      .4598
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .515    P= .046    P= .000    P= .000    P= .000

P1     -.0027      .0406     -.0267     -.0339      .0458
      (  537)    (  537)    (  537)    (  537)    (  537)
      P= .949    P= .348    P= .536    P= .433    P= .290

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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      P E A R S O N   C O R R E L A T I O N

             GROUP       SEX        HSUM       MSUM       SUM

P2          -.0552     -.1621      .2532      .3763      .5661
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .202    P= .000    P= .000    P= .000    P= .000

P3          -.0903     -.1091      .3302      .4237      .6668
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .036    P= .011    P= .000    P= .000    P= .000

P4          -.0347      .0576      .0290      .0932      .1510
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .423    P= .182    P= .503    P= .031    P= .000

P5          -.0125      .0505      .1475      .2324      .3465
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .772    P= .243    P= .001    P= .000    P= .000

P6          -.0772     -.1147      .1827      .2430      .4404
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .074    P= .008    P= .000    P= .000    P= .000

P7          -.0855     -.0163      .1997      .2816      .4768
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .048    P= .707    P= .000    P= .000    P= .000

P8          -.1075     -.0421      .3609      .3651      .5962
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .013    P= .330    P= .000    P= .000    P= .000

CHINESE     -.1448      .2045      .3199      .3633      .4145
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .001    P= .000    P= .000    P= .000    P= .000

MATHE       -.1321     -.0527      .4091      .6150      .6748
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .002    P= .223    P= .000    P= .000    P= .000

QP1         -.0673      .0168      .1981      .1976      .2538
           (  537)    (  537)    (  537)    (  537)    (  537)
           P= .119    P= .699    P= .000    P= .000    P= .000

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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- - - A R S O N   C O R R E L A T I O N

           GROUP       SEX         HSUM        MSUM        SUM

QP2       -.0262      -.2243       .3228       .3014       .3546
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .545     P= .000     P= .000     P= .000     P= .000

QP3       -.0706      -.1066       .1954       .1580       .2075
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .101     P= .013     P= .000     P= .000     P= .000

QP4       -.0520      -.1341       .1476       .1172       .2219
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .229     P= .002     P= .001     P= .007     P= .000

QP5       -.0951      -.0831       .0794       .0663       .1140
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .028     P= .054     P= .066     P= .125     P= .008

QP6       -.0181       .0565       .1984       .1998       .2275
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .675     P= .191     P= .000     P= .000     P= .000

QP7        .0357      -.1076       .2196       .1880       .2358
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .409     P= .013     P= .000     P= .000     P= .000

QP8        .0057      -.0342       .1862       .0375       .1301
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .894     P= .429     P= .000     P= .386     P= .003

QP9       -.0392      -.0392       .2904       .4000       .4532
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .365     P= .365     P= .000     P= .000     P= .000

QP10      -.2182      -.0400       .0930       .1727       .1593
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .000     P= .355     P= .031     P= .000     P= .000

QP11      -.1247      -.0702       .2118       .2371       .2840
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .004     P= .104     P= .000     P= .000     P= .000
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 - P E A R S O N   C O R R E L A T I O N

            GROUP        SEX          HSUM         MSUM         SUM

QP12      -.0298      -.0148        .1390        .0955        .1585
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .491     P= .731      P= .001      P= .027      P= .000

Qp13      -.1476       .0510        .1060        .1165        .1865
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .001     P= .238      P= .014      P= .007      P= .000

QP14      -.0267      -.0267        .1707        .1775        .2733
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .536     P= .536      P= .000      P= .000      P= .000

QP15      -.0167      -.0268        .0183        .0807        .0362
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .700     P= .535      P= .672      P= .062      P= .403

QP16      -.0042      -.1536        .1351        .1571        .1700
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .923     P= .000      P= .002      P= .000      P= .000

QP17      -.0739      -.0316        .1737        .1811        .2303
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .087     P= .465      P= .000      P= .000      P= .000

QP18      -.0750       .0369        .1836        .1887        .2098
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .083     P= .393      P= .000      P= .000      P= .000

QP19       .0470      -.0674        .2490        .2118        .2727
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .277     P= .119      P= .000      P= .000      P= .000

QP20      -.1704      -.0032        .1207        .1599        .1684
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .000     P= .941      P= .005      P= .000      P= .000

QP21      -.0947      -.0669        .2218        .3210        .3647
          (  537)     (  537)      (  537)      (  537)      (  537)
          P= .028     P= .121      P= .000      P= .000      P= .000

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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- P E A R S O N   C O R R E L A T I O N

          GROUP        SEX         HSUM        MSUM        SUM

Qp22    -.1519      -.0392       .2242       .4321       .4153
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .000     P= .365     P= .000     P= .000     P= .000

QP23    -.1236      -.0430       .3811       .4378       .4976
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .004     P= .320     P= .000     P= .000     P= .000

QP24    -.0738      -.0851       .3097       .1691       .2824
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .086     P= .049     P= .000     P= .000     P= .000

QP25    -.0039       .0037       .1873       .0664       .1070
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .928     P= .932     P= .000     P= .124     P= .013

QP26    -.2354      -.0277       .3187       .3748       .4504
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .000     P= .522     P= .000     P= .000     P= .000

QP27    -.1265      -.0252       .2800       .2795       .3098
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .003     P= .559     P= .000     P= .000     P= .000

QP28    -.0397      -.0050       .3402       .3872       .4271
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .359     P= .908     P= .000     P= .000     P= .000

QP29    -.0229      -.0758       .3201       .2549       .3296
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .596     P= .079     P= .000     P= .000     P= .000

QP30    -.1150       .0006       .2717       .2788       .3095
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .008     P= .989     P= .000     P= .000     P= .000

QP31    -.1747      -.0065       .2600       .2508       .3713
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .000     P= .880     P= .000     P= .000     P= .000
        P E A R S O N   C O R R E L A T I O N

             GROUP        SEX        HSUM        MSUM        SUM

QP32        -.0886      -.0546       .2152       .1589       .2295
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .040     P= .206     P= .000     P= .000     P= .000

QP33        -.2737       .0399       .2258       .1221       .2011
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .000     P= .356     P= .000     P= .005     P= .000

QP34        -.1732      -.0923       .3008       .2667       .3182
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .000     P= .033     P= .000     P= .000     P= .000

QP35        -.1599      -.0502       .2420       .2591       .2893
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .000     P= .246     P= .000     P= .000     P= .000

QP36        -.1482      -.0099       .3320       .3710       .4553
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .001     P= .819     P= .000     P= .000     P= .000

QP36        -.1748       .0853       .2368       .2379       .3368
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .000     P= .048     P= .000     P= .000     P= .000

QP38         .0481      -.0866       .3519       .1272       .2455
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .266     P= .045     P= .000     P= .003     P= .000

QP39        -.0163      -.0163       .0981       .0438       .1130
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .706     P= .706     P= .023     P= .311     P= .009

QP40        -.0268      -.0873       .2719       .1879       .2979
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .536     P= .043     P= .000     P= .000     P= .000

PPSUM  M    -.2097      -.0979       .5720       .5515       .6911
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .000     P= .023     P= .000     P= .000     P= .000

COEFFICIENT / (CASES) / 2-TAILED SIG)
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-- PEARSON CORRELATION

           GROUP       SEX        HSUM       MSUM       SUM

QF1       -.1156      .0182      .1329      .2499      .2719
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .007    P= .675    P= .002    P= .000    P= .000

QF2       -.1465     -.1806      .2452      .2091      .2640
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .001    P= .000    P= .000    P= .000    P= .000

QF3       -.1167     -.0906      .1642      .1040      .1818
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .006    P= .036    P= .000    P= .016    P= .000

QF4       -.1559     -.2338      .2150      .1499      .2292
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .000    P= .000    P= .000    P= .000    P= .000

QF5       -.0574     -.0437      .1261      .1827      .2078
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .184    P= .312    P= .003    P= .000    P= .000

QF6       -.0816     -.1218      .1567      .1781      .1985
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .059    P= .005    P= .000    P= .000    P= .000

QF7       -.0910     -.0627      .1604      .0934      .1601
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .035    P= .147    P= .000    P= .030    P= .000

QF8       -.0449     -.0449      .1958      .1111      .1554
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .299    P= .299    P= .000    P= .010    P= .000

QF9       -.1795     -.0893      .2632      .3995      .4051
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .000    P= .039    P= .000    P= .000    P= .000

QF10      -.2051     -.0642      .1715      .2076      .2100
         ( 537)     ( 537)     ( 537)     ( 537)     ( 537)
         P= .000    P= .137    P= .000    P= .000    P= .000

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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- P E A R S O N   C O R R E L A T I O N

          GROUP       SEX        HSUM       MSUM       SUM

QF11     -.1612     -.0579      .2401      .2390      .2618
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .000    P= .180    P= .000    P= .000    P= .000

QF12     -.1323     -.1093      .1815      .0858      .1525
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .002    P= .011    P= .000    P= .047    P= .000

QF13     -.1772     -.0576      .2798      .2224      .2799
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .000    P= .183    P= .000    P= .000    P= .000

QF14     -.1287     -.0910      .2211      .2790      .2682
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .003    P= .035    P= .000    P= .000    P= .000

QF15     -.1162     -.2176      .0423      .0095     -.0118
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .007    P= .000    P= .328    P= .825    P= .785

QF16     -.2798     -.1372      .0117      .1097      .0931
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .000    P= .001    P= .786    P= .011    P= .031

QF17     -.1356     -.1094      .1819      .1583      .2018
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .002    P= .011    P= .000    P= .000    P= .000

QF18     -.1178     -.1660      .1724      .1403      .1780
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .006    P= .000    P= .000    P= .001    P= .000

QF19     -.1421     -.1166      .2611      .2635      .3060
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .001    P= .007    P= .000    P= .000    P= .000

QF20     -.1704     -.0192      .0999      .0317      .0851
         (  537)    (  537)    (  537)    (  537)    (  537)
         P= .000    P= .656    P= .021    P= .464    P= .049

  COEFFICIENT / (CASES) / 2-TAILED SIG)
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-- PEARSON CORRELATION

          GROUP       SEX        HSUM       MSUM        SUM

QF21     -.0053      .0815      .2352      .3199      .3071
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .902    P= .059    P= .000    P= .000    P= .000

QF22     -.2120     -.0454      .2468      .3875      .3984
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .000    P= .293    P= .000    P= .000    P= .000

QF23     -.1981     -.0082      .3406      .4385      .4902
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .000    P= .850    P= .000    P= .000    P= .000

QF24     -.3039     -.1828      .3453      .2902      .3600
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .000    P= .000    P= .000    P= .000    P= .000

QF25     -.0427     -.1366      .1605      .0578      .1203
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .323    P= .002    P= .000    P= .181    P= .005

QF26     -.1525      .0001      .3641      .4472      .4895
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .000    P= .999    P= .000    P= .000    P= .000

QF27     -.1444     -.0773      .2524      .2772      .3522
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .001    P= .074    P= .000    P= .000    P= .000

QF28     -.0142      .0955      .2372      .3374      .3409
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .742    P= .027    P= .000    P= .000    P= .000

QF29     -.1226     -.1389      .2458      .1947      .2638
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .004    P= .001    P= .000    P= .000    P= .000

QF30     -.1353      .0328      .2978      .2963      .3240
        (  537)    (  537)    (  537)    (  537)    (  537)
        P= .002    P= .449    P= .000    P= .000    P= .000

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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- PEARSON CORRELATION

          GROUP        SEX          HSUM         MSUM         SUM

QF31     -.2484       -.0137        .1473        .2462        .2603
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .000      P= .751      P= .001      P= .000      P= .000

QF32     -.0715       -.0989        .1410        .0689        .1537
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .098      P= .022      P= .001      P= .111      P= .000

QF33     -.1205       -.0473        .1652        .1772        .2053
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .005      P= .273      P= .000      P= .000      P= .000

QF34     -.2692       -.1474        .3011        .2770        .3530
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .000      P= .001      P= .000      P= .000      P= .000

QF35     -.1856       -.0077        .1563        .2486        .2931
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .000      P= .859      P= .000      P= .000      P= .000

QF36     -.2527       -.0364        .3184        .3445        .4176
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .000      P= .400      P= .000      P= .000      P= .000

QF37     -.1233       -.0283        .2051        .1588        .2395
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .004      P= .514      P= .000      P= .000      P= .000

QF38      .0075       -.1465        .3082        .1903        .2739
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .863      P= .001      P= .000      P= .000      P= .000

QF39     -.3253       -.1425        .1404        .0695        .1111
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .000      P= .001      P= .001      P= .108      P= .010

QF40     -.0776       -.1426        .2224        .1602        .2240
        (  537)      (  537)      (  537)      (  537)      (  537)
        P= .072      P= .001      P= .000      P= .000      P= .000
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- P E A R S O N   C O R R E L A T I O N

           GROUP       SEX        HSUM        MSUM        SUM

PPSUM    -.3304      -.1711       .4939       .5058       .6037
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .000     P= .000     P= .000     P= .000     P= .000

 F01     -.0077      -.1675       .0282       .0200       .0163
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .858     P= .000     P= .515     P= .644     P= .707

 F02     -.0440       .0480      -.0117      -.0538      -.0728
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .309     P= .267     P= .787     P= .213     P= .092

 F03      .0781       .0625      -.0189       .0616       .0545
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .071     P= .148     P= .662     P= .154     P= .207

 F04     -.0372       .0512       .0016      -.0274      -.0134
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .389     P= .236     P= .970     P= .527     P= .757

 F05     -.0592      -.0592       .0189       .0056      -.0202
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .170     P= .170     P= .663     P= .897     P= .641

 F06     -.0163      -.0551       .0234       .0438       .0487
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .706     P= .202     P= .588     P= .311     P= .260

 F07      .0158       .0158       .0002      -.0076       .0089
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .714     P= .714     P= .996     P= .861     P= .838

 F08     -.0269      -.0269       .0791       .0297       .0553
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .534     P= .534     P= .067     P= .492     P= .200

 F09      .0019      -.0592       .0393       .0056       .0313
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .964     P= .170     P= .363     P= .897     P= .469

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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-- P E A R S O N   C O R R E L A T I O N

            GROUP       SEX         HSUM        MSUM        SUM

M01        -.0417      -.1378       .1507       .1242       .1366
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .335     P= .001     P= .000     P= .004     P= .002

M02        -.0488       .0196      -.1176      -.0871      -.1146
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .259     P= .651     P= .006     P= .044     P= .006

M03        -.0030       .0157       .0583       .0783       .0754
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .944     P= .716     P= .177     P= .070     P= .081

M04        -.1113       .0529      -.0360      -.0518      -.0298
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .010     P= .221     P= .405     P= .231     P= .491

M07        -.1475      -.1475      -.0903      -.0919      -.0880
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .001     P= .001     P= .037     P= .033     P= .042

M08         .0446      -.0418       .0061      -.0565      -.0207
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .302     P= .333     P= .888     P= .191     P= .633

M09         .2278       .1437       .0558       .0482       .0429
           (  537)     (  537)     (  537)     (  537)     (  537)
           P= .000     P= .001     P= .196     P= .265     P= .321
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  - - - -  P E A R S O N   C O R R E L A T I O N

          PPSUM       PFSUM       CHINESE     MATHE       INTERV

H1         .1807       .2108       .1706       .1641      -.0033
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .000     P= .000     P= .000     P= .000     P= .938

H2         .3242       .3119       .2116       .2394       .0606
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .000     P= .000     P= .000     P= .000     P= .161

H3         .0993       .0729      -.0156       .0600      -.0123
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .021     P= .091     P= .716     P= .165     P= .776

H4         .1674       .1878       .1387       .1509       .0703
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .000     P= .000     P= .001     P= .000     P= .104

H5         .1232       .1259       .1524       .0740       .0012
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .004     P= .003     P= .000     P= .087     P= .978

H6         .0559       .0227       .0620       .1222      -.0643
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .196     P= .599     P= .151     P= .005     P= .137

H7         .0874       .0445      -.0826      -.0185       .0679
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .043     P= .303     P= .056     P= .669     P= .116

H8         .0475       .0161      -.0173      -.0851      -.0031
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .272     P= .709     P= .689     P= .049     P= .943

H9         .3604       .3114       .2162       .3150       .0598
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .000     P= .000     P= .000     P= .000     P= .167

H10        .1482       .0877       .0794       .0284       .0079
        (  537)     (  537)     (  537)     (  537)     (  537)
        P= .001     P= .042     P= .066     P= .512     P= .856

  COEFFICIENT / (CASES) / 2-TAILED SIG)
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- - P E A R S O N   C O R R E L A T I O N

          PFSUM       CHINESE     MATHE       INTERV      PPSUM

H11        .1538       .0972       .1776       .0412       .1520
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .000     P= .024     P= .000     P= .340     P= .000

H12        .0256       .0375       .1006       .0197       .0196
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .554     P= .386     P= .020     P= .648     P= .650

H13        .2573       .1763       .2452       .0448       .3263
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .000     P= .000     P= .000     P= .300     P= .000

H14        .1690       .0771       .1158       .0438       .2077
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .000     P= .074     P= .007     P= .311     P= .000

H15        .4543       .2877       .3790       .0983       .4469
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .000     P= .000     P= .000     P= .023     P= .000

H16        .1484       .1299       .0444       .0624       .2378
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .001     P= .003     P= .305     P= .149     P= .000

H17        .0633      -.0041       .0394       .0658       .1229
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .143     P= .925     P= .362     P= .128     P= .004

H18        .0674       .0691       .0458       .0230       .1391
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .118     P= .109     P= .289     P= .594     P= .001

H19        .3579       .2267       .3527       .0759       .4073
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .000     P= .000     P= .000     P= .079     P= .000

P1         .0284       .0558       .0070       .0187       .0091
         (  537)     (  537)     (  537)     (  537)     (  537)
         P= .512     P= .197     P= .871     P= .665     P= .834

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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        P E A R S O N   C O R R E L A T I O N

              PFSUM       CHINESE      MATHE       INTERV    PPSUM

P2             .3071        .1527        .3565       .0786    .3386
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .000      P= .000     P= .069  P= .000

P3             .3968        .2528        .4852       .1035    .4685
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .000      P= .000     P= .016  P= .000

P4             .0233        .0435        .0457       .0266    .0907
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .590      P= .314      P= .290     P= .539  P= .036

P5             .1514        .1446        .1719      -.0746    .2058
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .001      P= .000     P= .084  P= .000

P6             .2077        .1731        .2960       .1132    .2535
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .000      P= .000     P= .009  P= .000

P7             .2497        .1901        .3009       .0331    .2561
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .000      P= .000     P= .445  P= .000

P8             .3829        .2820        .4408       .1352    .4439
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .000      P= .000     P= .002  P= .000

CHINESE        .5693       1.0000        .5267       .0850    .5193
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .         P= .000     P= .049  P= .000

MATHE          .6187        .5267       1.0000       .1522    .6659
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .000      P= .        P= .000  P= .000

QP1            .3546        .3187        .3423       .0433    .4188
             (  537)      (  537)      (  537)     (  537)  (  537)
             P= .000      P= .000      P= .000     P= .317  P= .000
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-- PEARSON CORRELATION

          PFSUM       CHINESE      MATHE       INTERV      PPSUM

QP2        .3579       .2320       .3717       .0366       .4228
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .000     P= .000     P= .397     P= .000

QP3        .2694       .1395       .1333       .0713       .2999
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .001     P= .002     P= .099     P= .000

QP4        .1965       .1156       .2126       .0393       .2719
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .007     P= .000     P= .364     P= .000

QP5        .2055       .1528       .1137       .0753       .2428
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .000     P= .008     P= .081     P= .000

QP6        .2186       .2049       .1998       .0634       .3013
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .000     P= .000     P= .142     P= .000

QP7        .2654       .1542       .2240       .0895       .3474
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .000     P= .000     P= .038     P= .000

QP8        .1911       .1548       .1013       .0005       .2595
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .000     P= .019     P= .990     P= .000

QP9        .3428       .2398       .4168       .0674       .4374
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .000     P= .000     P= .119     P= .000

QP10       .2243       .1241       .1312       .0561       .2933
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .004     P= .002     P= .194     P= .000

QP11       .2138       .1099       .2429       .0470       .3396
         ( 537)      ( 537)      ( 537)      ( 537)      ( 537)
         P= .000     P= .011     P= .000     P= .277     P= .000

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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- - P E A R S O N   C O R R E L A T I O N

            PFSUM      CHINESE     MATHE      INTERV     PPSUM

QP12        .1530       .1066       .0813      .0409      .2794
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .013     P= .060    P= .345    P= .000

QP13        .2242       .1830       .1643      .0923      .3083
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .000     P= .000    P= .032    P= .000

QP14        .2620       .1312       .2626     -.0021      .3459
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .002     P= .000    P= .961    P= .000

QP15       -.0262       .0118       .0159      .0038      .0536
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .545     P= .785     P= .713    P= .929    P= .215

QP16        .2576       .1001       .3417      .0700      .3368
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .020     P= .000    P= .105    P= .000

QP17        .2458       .1865       .2156      .0471      .3413
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .000     P= .000    P= .276    P= .000

QP18        .2685       .2447       .2525      .0982      .3756
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .000     P= .000    P= .023    P= .000

QP19        .2370       .1511       .2385      .0264      .3790
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .000     P= .000    P= .542    P= .000

QP20        .1983       .1719       .2154     -.0064      .2982
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .000     P= .000    P= .883    P= .000

QP21        .4452       .3163       .4185      .0867      .5194
         (   537)    (   537)    (   537)   (   537)   (   537)
         P= .000     P= .000     P= .000    P= .045    P= .000

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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-- PEARSON CORRELATION

          PFSUM       CHINESE      MATHE       INTERV      PPSUM

QP22      .3869        .2811       .4599        .0818       .4977
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .000     P= .000      P= .058     P= .000

QP23      .5527        .3309       .5840        .1016       .6766
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .000     P= .000      P= .018     P= .000

QP24      .2798        .1441       .1618        .1579       .4257
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .001     P= .000      P= .000     P= .000

QP25      .1628        .1017       .0582       -.0014       .2588
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .018     P= .178      P= .974     P= .000

QP26      .5418        .4143       .4897        .1599       .6418
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .000     P= .000      P= .000     P= .000

QP27      .3709        .2556       .3409        .1121       .4832
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .000     P= .000      P= .009     P= .000

QP28      .4147        .3114       .4206        .1019       .5604
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .000     P= .000      P= .018     P= .000

QP29      .3460        .3375       .2419        .0725       .4659
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .000     P= .000      P= .093     P= .000

QP30      .3086        .3138       .2167        .0097       .4661
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .000     P= .000      P= .822     P= .000

QP31      .3473        .2458       .3309        .0401       .5142
        (  537)      (  537)     (  537)      (  537)     (  537)
        P= .000      P= .000     P= .000      P= .354     P= .000
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- P E A R S O N   C O R R E L A T I O N

           PFSUM        CHINESE      MATHE        INTERV      PPSUM

QP32        .2663        .1441        .1805        .0334       .4023
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .001      P= .000      P= .440     P= .000

QP33        .2707        .2239        .1030        .0311       .3804
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .000      P= .017      P= .473     P= .000

QP34        .4027        .2692        .3014        .1495       .4625
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .000      P= .000      P= .001     P= .000

QP35        .3312        .2387        .3461        .0441       .4471
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .000      P= .000      P= .307     P= .000

QP36        .4443        .2956        .4639        .0358       .6002
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .000      P= .000      P= .407     P= .000

QP37        .3295        .2074        .3407        .0712       .4634
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .000      P= .000      P= .099     P= .000

QP38        .3015        .2136        .1477        .1090       .4137
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .000      P= .001      P= .011     P= .000

QP39        .0796        .0715        .0731       -.0210       .0708
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .065      P= .098      P= .090      P= .628     P= .101

QP40        .2848        .1397        .2452        .0733       .4020
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .001      P= .000      P= .090     P= .000

PPSUM       .7456        .5193        .6659        .1592      1.0000
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .000      P= .000      P= .000     P= .

COEFFICIENT / (CASES) / 2-TAILED SIG)
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- - P E A R S O N   C O R R E L A T I O N

              PFSUM        CHINESE      MATHE        INTERV       PPSUM

QF1            .3189        .2290        .2832        .0722        .2780
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .000      P= .000      P= .095      P= .000

QF2            .4525        .2221        .2948        .0860        .2958
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .000      P= .000      P= .046      P= .000

QF3            .3339        .2255        .1114        .0620        .2035
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .000      P= .010      P= .151      P= .000

QF4            .3750        .0881        .1647        .0658        .1847
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .041      P= .000      P= .128      P= .000

QF5            .2535        .1957        .1708        .0638        .1883
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .000      P= .000      P= .140      P= .000

QF6            .3636        .1558        .2044        .0495        .2327
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .000      P= .000      P= .252      P= .000

QF7            .3145        .1150        .1146        .1060        .1892
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .008      P= .008      P= .014      P= .000

QF8            .3695        .2112        .1068        .0678        .2388
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .000      P= .013      P= .042      P= .000

QF9            .5347        .3156        .4024        .0722        .4489
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .000      P= .000      P= .095      P= .000

QF10           .3624        .2439        .1974        .0206        .2833
             (  537)      (  537)      (  537)      (  537)      (  537)
             P= .000      P= .000      P= .000      P= .633      P= .000
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- - P E A R S O N   C O R R E L A T I O N

            PFSUM        CHINESE       MATHE        INTERV     PPSUM

QF11         .3812         .1914        .2125        .0385      .2177
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .000      P= .000      P= .374    P= .000

QF12         .3429         .1724        .1121        .0240      .1872
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .000      P= .009      P= .579    P= .000

QF13         .4212         .2846        .2794        .0214      .3621
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .000      P= .000      P= .621    P= .000

QF14         .4145         .2094        .2639        .1060      .3410
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .000      P= .000      P= .014    P= .000

QF15         .2295         .0698        .0069       -.0684      .0367
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .106      P= .873      P= .113    P= .397

Qf16         .3205         .1196        .1850        .0175      .1209
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .006      P= .000      P= .686    P= .005

QF17         .3217         .0793        .1550        .0161      .2298
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .066      P= .000      P= .709    P= .000

QF18         .3628         .2295        .1430       -.0290      .2132
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .000      P= .001      P= .503    P= .000

QF19         .3646         .1999        .2586        .0455      .2794
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .000      P= .000      P= .292    P= .000

QF20         .3026         .1847        .1276        .0733      .2078
           (  537)       (  537)      (  537)      (  537)    (  537)
           P= .000       P= .000      P= .003      P= .090    P= .000


(COEFFICIENT / (CASES) / 2-TAILED SIG)
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- P E A R S O N   C O R R E L A T I O N

            PFSUM       CHINESE       MATHE        INTERV       PPSUM

QF21         .4183        .3519        .3694        .0789        .3899
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .068      P= .000

QF22         .5225        .3028        .4125        .0710        .4670
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .100      P= .000

QF23         .6822        .4331        .5570        .1255        .5421
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .004      P= .000

QF24         .6241        .3090        .2921        .1353        .5267
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .002      P= .000

QF25         .3689        .1645        .0859        .0446        .1867
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .047      P= .302      P= .000

QF26         .6843        .4590        .5801        .1211        .5984
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .005      P= .000

QF27         .5104        .2988        .4344        .0714        .4393
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .098      P= .000

QF28         .4920        .3884        .4083        .0488        .4111
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .259      P= .000

QF29         .4648        .3202        .2158        .0218        .3501
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .614      P= .000

QF30         .4704        .3476        .2762        .0011        .3890
          (   537)     (   537)     (   537)     (   537)     (   537)
          P= .000      P= .000      P= .000      P= .980      P= .000
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 - P E A R S O N   C O R R E L A T I O N

            PFSUM      CHINESE      MATHE       INTERV     PPSUM

QF31        .4777        .2527       .2665       .0652      .3693
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .000     P= .131    P= .000

QF32        .3951        .1727       .1771       .0415      .2821
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .000     P= .338    P= .000

QF33        .3543        .2268       .1966       .0273      .3135
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .000     P= .528    P= .000

QF34        .5811        .3068       .3599       .1092      .4666
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .000     P= .011    P= .000

QF35        .4394        .2825       .3910       .1373      .3483
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .000     P= .001    P= .000

QF36        .6302        .3709       .4948       .1151      .5187
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .000     P= .008    P= .000

QF37        .4053        .2011       .2354       .0668      .3111
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .000     P= .122    P= .000

QF38        .4562        .2544       .2551       .0840      .3171
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .000     P= .052    P= .000

QF39        .4652        .2425       .1415       .1131      .1862
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .000     P= .001     P= .009    P= .000

QF40        .4031        .1493       .1749       .0833      .2382
          (  537)      (  537)     (  537)     (  537)    (  537)
          P= .000      P= .001     P= .000     P= .054    P= .000

(COEFFICIENT / (CASES) / 2-TAILED SIG)
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- P E A R S O N   C O R R E L A T I O N

          PFSUM        CHINESE      MATHE        INTERV       PPSUM

PFSUM    1.0000         .5693        .6187        .1520        .7456
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .          P= .000      P= .000      P= .000      P= .000

F01       .1261         .0109        .0077       -.0433        .0648
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .003       P= .801      P= .859      P= .316      P= .134

F02      -.0036        -.0514       -.1292        .0147       -.0645
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .934       P= .234      P= .003      P= .734      P= .135

F03      -.0595         .1054        .1356        .0079        .0317
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .169       P= .015      P= .002      P= .855      P= .464

F04       .0538         .0039        .0268        .0805        .0263
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .214       P= .927      P= .536      P= .062      P= .543

F05       .0014        -.0499       -.0546       -.0132       -.0362
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .974       P= .249      P= .207      P= .760      P= .402

F06       .0572         .0025        .0149        .0729        .0166
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .185       P= .953      P= .731      P= .092      P= .700

F07      -.0457        -.0628       -.0074       -.0535       -.0353
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .291       P= .146      P= .864      P= .215      P= .414

F08       .0283         .0038        .0116       -.0266        .0511
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .512       P= .929      P= .789      P= .539      P= .237

F09       .0183         .0003        .0348       -.0132        .0524
        (  537)       (  537)      (  537)      (  537)      (  537)
        P= .672       P= .994      P= .420      P= .760      P= .226
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-- PEARSON CORRELATION COE

           PFSUM       CHINESE      MATHE       INTERV       PPSUM

M01         .1650        .0665        .0503       -.0436       .0893
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .000      P= .124      P= .244      P= .313     P= .039

M02        -.0894       -.0951       -.1144        .0178      -.1032
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .038      P= .028      P= .006      P= .680     P= .017

M03         .0609        .1074        .1799        .0059       .0874
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .158      P= .013      P= .000      P= .891     P= .043

M04         .0270        .0461       -.0121       -.0249      -.0123
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .532      P= .286      P= .779      P= .565     P= .777

M07        -.0476       -.1198       -.1651       -.0361      -.1254
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .271      P= .005      P= .000      P= .404     P= .004

M08        -.0261        .0017       -.0429       -.0093      -.0106
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .547      P= .968      P= .321      P= .829     P= .803

M09        -.0091        .0529        .0442        .0307       .0769
          (  537)      (  537)      (  537)      (  537)     (  537)
          P= .833      P= .221      P= .307      P= .478     P= .075
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- - P E A R S O N   C O R R E L A T I O N   C O E

              OPCRT    OPTRS    OPFML    OFCRT    OFTRS    OFFML

GROUP       -.1517   -.2283   -.1699   -.2173   -.2692   -.3732
             ( 537)   ( 537)   ( 537)   ( 537)   ( 537)   ( 537)
            P= .000  P=.000   P=.000   P=.000   P=.000   P=.000

COEFFICIENT / (CASES) / 2-TAILED SIG)
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APPENDIX E

THE DATA FROM INTERVIEWS

Twenty-eight students were selected from three schools. Students from the selective school were not interviewed. Fourteen experimental students and 14 control students(two to three students from each class) were selected randomly. Both correct and incorrect responses were recorded and analyzed. The data are presented for selected questions in order of the frequencies of the students' responses, the high frequency is put before the low frequency in the case listing. The questions selected were those that were difficult for the students and provided the best opportunity for learning about students' misconceptions.

DATA AND ANALYSES

A. Concept of Temperature

Selected responses to question 1 of the posttest are listed below.

1. Responses to distractor 2 on the posttest question 1. Distractor 2 was the correct answer.

Most frequent student response: My answer is distractor 2 because thermometers are designed to measure the degree of hotness and coldness for certain purposes.

Second most frequent response: A thermometer can not measure how much of heat that a substance holds. Therefore my answer is distractor 2.

Third most frequent response: Thermometers are designed by applying properties that the liquid in a thermometer can expand when it is heated and contract at cooling so my answer is distractor 2.

2. Responses to incorrect distractor on question 1.

Most frequent response for incorrect distractor to question 1: I believe that a thermometer can measure both the amount of heat held by a substance and the degree of hotness because a substance that holds more heat also has higher temperature. Therefore my answer is distractor 3.

3. Examples of response that were incorrect on the posttest and corrected during the interview.

Teacher: In your posttest your answer was distractor 3. Why did you change your answer to distractor 2 just now?

Student: I found the mass of a substance was also one of the elements which can contribute the quantity of total heat.

Summary of Responses to Posttest Question 1.

Students responded to the definition of temperature based on their concrete experiences in observing or using thermometers. This finding implies that providing concrete experiences for students in using thermometers in the classes is very important for their learning such as providing a task for constructing their own thermometers.

B. Kinetic Theory

Selected responses to question 6 of the posttest are listed below.

1. Responses to distractor 3 on the posttest question 6. Distractor 3 was the correct answer.

Most frequent student response: The evidence in A, B, and C are all correlated to temperature increasing.

Second most frequent response: If we heat a liquid substance we know that its volume will expand and know the molecules of the substance move faster than before. Due to the gain of speed of a molecule its kinetic energy increases.

2. Responses to incorrect distractor on question 6 of the posttest.

Most frequent response for incorrect distractor to the question 6: My answer is distractor 2.

Teacher: Could you explain your answer?

Student: No, I can not explain it. I guessed the answer.

Second most frequent response for incorrect distractor to the question 6: My answer is distractor 1.

Teacher: Could you explain your answer?

Student: You know the volume of a substance is expanding when its temperature is raising.

Teacher: How about the relation between the speed of a molecule and its kinetic energy?

Student: I am not sure.

3. Examples of response that were incorrect on the posttest and corrected during the interview.

Teacher: In your posttest your answer was distractor 4. You changed your answer from distractor 4 to distractor 3 at this point. Could you explain why?

Student: I have understood the point that the increase of temperature can cause the increase of molecular speed.

Teacher: Who helped you?

Student: I learned it from instructional material after the posttest.

Summary of Responses to Posttest Question 6.

In the analysis of this question the finding indicates that student reasoning was based on concrete experiences and prior knowledge in the correlations among the variables concerned. For instance, a student could correlate the speed of a molecule and its kinetic energy; then he could recognize that the increase of speed of a molecule would result in the increase of its kinetic energy.

Students raised examples which were based on their concrete experiences such as that heating a cup of liquid would lead to expansion of its volume. It indicated the importance of student prior knowledge.

By investigating the background of the students it was found that the students who could do formal thinking could correlate the multiple variables better than those who had a reasoning level below that of formal thinking. The finding implies that it is important to provide opportunities to integrate multiple facets of a natural phenomenon in the instructional material that would improve student reasoning ability.

Selected responses to question 39 of the posttest are listed below.

1. Responses correct answer on the posttest question 39.

Most frequent student response: My answer is 'the same'.

Teacher: Could you explain your answer?

Student: The instructional material notes that the average of molecular kinetic energy is related to its temperature. Because these three cups of liquid got the same temperatures so their average molecular kinetic energy are the same.

2. Responses to incorrect answer to the question 39.

Most frequent response for incorrect answer to question 39 of the posttest: My answer is mercury.

Teacher: Could you explain your answer?

Student: Mercury has the smallest specific heat so the space between their molecules is the smallest so that it can get the largest average molecular kinetic energy.

Teacher: How do you know the molecular space of mercury is the smallest?

Student: The density of mercury is the largest.

Teacher: Could you explain why the smallest molecular space results in the largest average kinetic energy?

Student: The short space could make a particle quickly to speed up.

Teacher: ....?

The second most frequent response for an incorrect answer to the question 39 of the posttest: My answer is water because water has the largest specific heat among the these materials and the largest amount of heat was absorbed. Therefore the molecules of water got the largest average molecular kinetic energy among these three cups of liquid.

Teacher: Could you correlate between the average molecular kinetic energy and its temperature?

Student: It is hard to believe and reason.

The third most frequent response for an incorrect answer to question 39 of the posttest: My answer is mercury because it got smallest specific heat. Therefore it is the easiest to excite to get the largest molecular averagekinetic energy.

Teacher: Could you correlate between temperature and its molecular average kinetic energy?

Student: No, I still believe mercury is the correct answer because it absorbed the largest amount of heat among these three cups of liquid.

Teacher: It should absorb the least heat. Do you remember mercury with the least specific heat among them?

Student: Oh... I might get a wrong answer.

Teacher: Could you correlate between the temperature and molecular average kinetic energy again?

Student: The temperature is the measurement of the molecular average kinetic energy.

Teacher: If all these three cups of liquid have the same temperature. Which one had the largest average kinetic energy?

Student: It should be the same.

Summary of Responses to Posttest Question 39.

In this question very few students got their reasoning correct. Most of students had difficulty in realizing that the temperature was related to the molecular average kinetic energy because the same temperature change of different materials (with the same mass) takes different amounts of heat. The dialogues showed that learners tried to make their conclusions consistent with their prior knowledge to get an acceptable logic reasoning. It was hard for them to accept a concept if it conflicted with their pre-existing knowledge. One type of problem showed that the students refused to accept a new idea until they found they had a wrong answer.

The findings showed that the reasoning level assumed in the instructional materials for this item was beyond the concrete level of the learners. Students had difficulty in learning the content related to kinetic theory.

C. Specific Heat

Selected responses to question 12 of the posttest are listed below.

1. Responses to distractor 2 on the posttest question 12. Distractor 2 was the correct answer.

Most frequent student response: The specific heat of aluminum is the largest among the three kinds of metal so it would absorb the largest amount of heat when they raise to the same degrees of temperature.

Second most frequent response: According to the formula, $H = M S T$, Specific heat is proportional to the heat absorbed so my answer is distractor 2.

Third most frequent response:

Teacher: Your answer is correct. Could you explain it?

Student: I just guessed it.

2. Responses to incorrect distractor to question 12.

Student: I believe silver is the correct answer because its specific heat is the smallest.

Teacher: Could you explain your reason? Do you know that the smaller specific heat of a substance the smaller the heat absorbed in order to raise the same temperature?

Student: Of course, I should change my answer to aluminum.

Selected responses to question 25 of the posttest are listed below.

1. Responses to distractor C on the posttest question 25. Distractor C was the correct answer.

Most frequent student response: My answer is distractor C because more specific heat of a substance has to have a longer time to cool down.

Second most frequent response: My answer is distractor C because of the larger the specific heat of a substance the more difficult to change its temperature.

Third most frequent response:

Teacher: Your answer was distractor A in your test. At this point your answer is distractor C. Could you explain why?

Student: At that time I did believe that the smaller the specific heat of a substance needed the longer time to cool down. At this point I believe that the smaller specific heat of a substance absorb the less amount of heat. Therefore, I believe distractor C is a correct answer.

Selected responses to questions 38 and 40 of the posttest are listed below.

1. Responses to correct answers was mercury on both the posttest question 38 and 40.

Most frequent student response: Mercury is the answer in both questions 38 and 40 because the smaller specific heat of a substance is easier to raise up and cool down its temperature.

Second most frequent response:

Teacher: Your answer was water in the test. You changed your answer to mercury just now. Could you explain it?

Student: I did believe the largest specific heat of a substance came up the fastest in heat absorption. I was not very clear on the relationships between the specific heat and the rate of heat absorption of a substance. I do know the larger in specific heat the more difficult to change its temperature.

2. Responses to incorrect answers to questions 38 and 40.

Most frequent response for incorrect answer to questions 38 and 40 of the posttest:

Student: Because the condition of thermal states were the same I believed they needed the same period of time to raise their temperature up.

Student: I believe water is my answer.

Teacher: Could you explain your answer?

Student: The specific heat of water is the largest among them so it would be first one to raise its temperature from 25 to 75 degrees Celsius.

Summary of Responses to Posttest Questions 12, 25, 38 and 40.

Students based their reasoning on their concepts of laws that they knew. The concrete experiences obviously lead them to consolidate their laws. Lacking the correct laws in their cognitive structure, students based their reasoning on intuition. They did not get their conclusions from scientific reasoning. This finding implies the importance to teach the scientific laws in the instructional materials based on concrete experiences so that students can apply the laws in a confident way. Some students could not complete their reasoning because of a lack of one or more propositions in their processes of reasoning. For instance, students could not respond with a correct answer until someone gave them a little hint somewhere in the process of their reasoning. In this study the interviewer found that many of the students could respond correctly if they were provided with one or more propositions. The finding implies the importance of procedural knowledge for the process of reasoning.

Therefore, providing opportunities for students to learn procedural knowledge in the instructional materials and in the classroom instruction might improve their learning, That is; to practice more concrete examples should improve reasoning.

In these four questions concerned with the topic of specific heat, students who got the laws, that is the more the specific heat of a substance the more time it takes to cool down, made a correct judgment. On the other hand lacking a correct concept of the laws to be applied, the students guessed at answers as a result of their incorrect reasoning.

E. Thermometer

Selected responses to question 15 of the posttest are listed below.

1. Responses to distractor 2 on the posttest question 15. Distractor 2 was the correct answer.

Most frequent student response: I believe distractor 2 is a correct answer.

Teacher: Why didn't you pick up distractor 3 as your answer in your posttest?

Student: The evidence shown in distractor 3 is one of cases included in the distractor 2 because expansion-contraction is one of properties of a substance when its temperature is changed.

Second most frequent response: I understand every substance has a certain property at a certain temperature if we look at a certain character of a substance. For instance, A substance can emit a certain color ray at a certain temperature.

2. Responses to incorrect distractor to question 15.

Student: I believe distractor 4 is a correct answer.

Teacher: Could you explain your answer?

Student: I haven't seen a person use two thermometers to measure temperature, that is, one for low temperature and another for high temperature at the same time.

Second most frequent response for incorrect answer to question 15 of the posttest: My answer is distractor 3 because I think proportion of a substance should be only way for measuring temperature precisely.

Third most frequent response for incorrect answer to question 15 of the posttest: My answer is distractor 1 because the property of expansion and contraction of a substance is only way to show the high or low on measurement of temperature.

Summary of Responses to Posttest Question 15.

It was found that if the instructional material stressed specific natural phenomena and ignored the generalization of concepts, incomplete reasoning result. The finding of this study indicated that many of the students had the concept but only the property of thermal expansion could be applied to construct thermometers. The finding implies that specific natural phenomena should be provided for students in combination with their generalized concepts.

F. Heat

Selected responses to question 20 of the posttest are listed below.

1. Responses to distractor 2 on the posttest question 20. Distractor 2 was the correct answer.

Most frequent student response: I believe heat is a kind of energy. Two matters with different temperature are put together. We can find the high temperature would decline and low temperature would increase at the final state. Heat flows from high temperature matter to low temperature matter no matter what the amount of heat they have.

2. Responses to incorrect distractor to question 20.

Most frequent response for incorrect answer to question 20: I believe that heat is composed of lots of invisible particles because only particles can displace from place to place.

Second most frequent response for incorrect answer to question 20:

Student: I believe that heat is transferred from a substance with a large amount of heat to one with less amount because the substance with larger amount of heat is always at a higher temperature than a substance with less heat.

3. Examples of response that were incorrect on the posttest and corrected during the interview.

Teacher: Your answer is distractor 3 in your posttest. Could you explain why you corrected your answer to distractor 2?

Student: I did believe that heat was composed of many invisible particles and that they could walk randomly. Evidence has shown me that collision can cause the generation of heat. Therefore, I believe that heat is a kind of energy rather than particles at this point.

Summary of Responses to Posttest Question 20.

Many grade 8 students still believed that heat was composed of invisible particles. The finding implied that more evidence should have been provided for the classes to show that heat is a kind of energy which can be converted to other kinds of energy.

Some students were found who were not clear about the concept that a small amount of heat can raise a substance to a very high temperature if its mass and specific heat are very small. Instructional materials should provide more concrete examples for students to deal with the concept.

G. Thermal Equilibrium.

Selected responses to question 24 of the posttest are listed below.

1. Responses to correct answer on the posttest question 24. Most frequent student response:

Student: I believe that all metal balls had 100 degrees Celsius because these metal balls took heat from hot water and got to thermal equilibrium at final state no matter what the value of its specific heat. The metal balls with their small specific heat therefore they took enough heat to get to thermal equilibrium very quickly.

Second most frequent response: I believe all of the metal balls are 100 degrees Celsius because the hot water is kept at 100 degrees Celsius for a period of time.

Teacher: Could you explain your reasoning more clearly?

Student: Because the metal balls and water are in thermal equilibrium state.

Teacher: Why did the temperature not drop below 100 degrees Celsius? Where did the heat come from?

Student: Do you remember that the water was heated continuously?

2. Responses to incorrect answer on question 24.

Most frequent response for incorrect answer to question 24 of the posttest: All of the three metal balls were more than 1000 degrees Celsius.

Teacher: Could you explain your answer? We put the balls in the hot water which was just 100 degrees Celsius. How could the temperatures of the metal balls be beyond 1000 degrees Celsius? Was it possible?

Student: It was possible because the metal balls had been still heating. The metal balls are about tenth of specific heat of water therefore their temperatures would increase very quickly and would get to 1000 degrees Celsius which is about ten times the temperature of the hot water.

Second most frequent response for incorrect answer to question 24 of the posttest:

Student: I don't know how to deal with this question.

Teacher: Did you investigate your experiment which we did to measure specific heat of a certain metal?

Student: Sure, I was wondering both the metal balls and the water were heated continuously and you said the water still was kept at 100 degrees Celsius for a period of time. Was the heat absorbed by the balls continuously? Otherwise where did the given heat go?

Teacher: Did you remember some of water changed its phase into steam at 100 degrees Celsius?

Student: I saw it. What was the meaning?

Teacher: The given heat had gone to steam.

Student: It means that both of the metal balls and the water all can kept at 100 degrees Celsius.

Teacher: You are right.

Summary of Responses to Posttest Question 24.

Students who did the experiment related to thermal equilibrium found that they could understand the correlation between multiple variables. Students knew thermal equilibrium from investigating the phenomena in their laboratory work rather than by knowing from a lecture. According to the dialogues above, the students who had concrete laboratory work used more reasonable thinking to deal with this question. They asked themselves in their reasoning on consistency for the variables they saw. Even lacking some information they still could get almost reasonable explanations for the natural phenomena. If they have more information they can understand they can learn. The finding implies the importance of the concrete experiences in observing, doing, and thinking in the classroom tasks to operate with multiple variables. It also implies the importance of the sequence of the subject matter. A wrong sequence in the subject material results a lack of information in reasoning therefore misconceptions come up.

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